POULTRY HUSBANDRY

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POULTRY HUSBANDRY

BY

MORLEY A. JULL

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U. S. Department of Agriculture

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PREFACE

The purpose intended in the preparation of the material in this book is to convey to its readers some conception of the background of the poultry industry, the fundamental principles involved in various poultry practices and up-to-date information concerning methods of poultry production. The more important economic factors in producing and marketing poultry products are given due consideration.

Success in poultry raising depends largely upon one's knowledge of the business and one's ability to produce and market poultry and poultry products most efficiently. Fundamental principles must be understood to some extent at least before the most economical methods can be practiced intelligently. For this reason the major aspects of poultry production and marketing are discussed, first, in respect to principles involved and, second, in respect to practices to be followed.

The discussion of fundamental principles involved should stimulate further research concerning the problems raised. The results of the various lines of research work are reviewed and an extensive list of literature references is given, so that the investigator, teacher and student each has a ready reference for review purposes.

The discussion of practices to be followed should be of considerable value to extension workers, farmers and commercial poultrymen.

The preparation of the book has been inspired in the spirit of rendering the greatest possible service to the poultry industry.

The author is deeply indebted to the following officials of the U. S. Department of Agriculture for reading and offering valuable suggestions in connection with the manuscript of the chapters accredited to each name: Mr. A. R. Lee, Chaps., I to IV, XV, XVI, XIX, and XX; Dr. H. C. McPhee, Chaps. VIII to XI; Dr. T. C. Byerly, Chaps. XII to XIV; Mr. H. W. Titus, Chaps. XXI to XXV; Dr. Eloise B. Cram and Dr. Hubert Bunyea, Chap. XXVI; Mr. R. R. Slocum, Chaps. XXVIII and XXIX.

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M. A. J.

Washington, D. C.,
April, 1930.

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POULTRY HUSBANDRY

CHAPTER I

THE NATURE AND USES OF POULTRY PRODUCTS

The development of the poultry industry to its present state has been brought about largely by the demand for poultry products in the human diet and by the relative economy in the production of these products in comparison with other animal food products. If people had never acquired a taste for the egg and flesh of the wild fowl, there probably would have been no poultry industry as we know it today. It is well to bear in mind, therefore, that the importance of an industry must be judged from the standpoint of the consumption as well as the production of its products.

In respect to consumption, there are few other commodities so widely used as poultry meat and eggs, the latter of which also have various industrial uses, as is the case with feathers. The world-wide use of poultry products becomes evident when it is realized that many kinds of poultry, which includes chickens, turkeys, guinea fowls, pheasants, peafowls, ostriches, ducks, geese and swans, are raised in practically all parts of the world and under a great variety of conditions. More individuals are directly interested in raising poultry than in the production of any other class of animals or any class of plants.

EGGS IN THE DIET

Eggs of all domesticated poultry are edible products, although the production and trade in eggs of turkeys, guinea fowls, pheasants, peafowls, ostriches, ducks, geese and swans are of relatively slight significance as compared with the production and trade in chicken eggs. In some countries during recent years, however, duck eggs have been used quite extensively as an article of diet.

Eggs are used in three ways: (1) in the shell, (2) as liquid eggs, and (3) as dried eggs. They enter consuming channels chiefly in the shell form, especially in the home, although bakers and confectioners also use considerable quantities. Frozen liquid eggs are used extensively in the bakeries in the making of cakes and other food products. The dried egg product is used in the making of pies, confections and sweet specialties.

Dietetic Value of Eggs.—The dietetic value of eggs has received considerable attention during recent years because of the demonstration of their relative richness in three important vitamins, A, B and D. Of course, eggs have long since been regarded as an important food product because of their protein content, their ease of digestibility, and the fact that they can be prepared in a great variety of appetizing ways.

The chief organic constituents of the muscle tissue and of the protoplasm of plant and animal cells generally are proteins, which are necessary for the construction and repair or maintenance of all animal tissues. Proteins are necessary ingredients of the food of all animals, including humans. The white or albumen of the egg is relatively rich in protein, as shown in Table 1. The value of egg protein in human nutrition is emphasized by Sherman (1927)[1] in the following statement: "Egg albumen, perhaps the most familiar of all proteins and one of the most often chosen to illustrate, in the laboratory, the property of proteins in general, will be seen to yield no glycine (*an amino-acid, protein being composed of a large number of amino-acids*) but to furnish all the other amino-acids in quite appreciable proportions. The feeding experiments show that with a diet adequate as regards all other factors animals may be maintained in normal nutrition and young animals may make normal growth with egg albumin as the sole protein food."[2]

Nutritive Value of Eggs.—McCollum and Simmonds (1925) also report the results of investigational work to determine the nutritive value of protein from chicken eggs. "Osborne and Mendel (1913 and 1915) state that egg white gave adequate growth in rats when they were given 18 per cent of the protein. Bond (1922) reported excellent growth in rats on diets in which 20 per cent of egg white formed the sole source of protein."

TABLE 1.—AVERAGE COMPOSITION OF EGGS

(Langworthy, 1917)

	Refuse, per cent	Water, per cent	Protein, per cent	Fat, per cent	Carbohydrates, per cent	Ash per cent	Fuel value per pound, calories[1]
Hen:							
Whole egg as purchased	11.2	65.5	11.9	9.3	.....	0.9	595
Whole egg, edible portion	....	73.7	13.4	10.5	.....	1.0	670
White	....	86.2	12.3	0.2	.....	0.6	230
Yolk	....	49.5	15.7	33.3	.....	1.1	1,645
Whole egg boiled, edible portion	....	73.2	13.2	12.0	.....	0.8	730

[1] These values were calculated on the assumption that protein and carbohydrates (each) yield 1,820 (or 4 calories per gram) calories per pound; and fat, 4,080 (or 9 calories per gram) calories per pound.

Concerning the digestibility of egg white, McCollum and Simmonds (1925) report that Rose and McLeod (1920) found the coefficient of

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[1] A complete list of references to the poultry literature cited in this book is given on pp. 574 to 620.

[2] SHERMAN, HENRY C., "Chemistry of Food and Nutrition." By permission of The Macmillan Company, publishers.

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digestibility for cooked egg white to be 82 to 86 per cent, for unbeaten raw whites 71 per cent, for beaten raw whites 83 per cent, and for half beaten raw whites 81 per cent. It is clear, therefore, that egg white is readily digested.

Fat in various human foods supplies fuel as a source of energy. The yolk is rich in a phosphorus-containing fat in emulsified form which is easily digested and readily absorbed.

Mineral elements are necessary for human nutrition in order to supply material for bone formation, to supply essential elements of the organic compounds which are the chief solid constituents of muscle tissues and blood cells, and to provide soluble salts held in solution in the fluids of the body. Eggs contain iron, calcium, sulphur and phosphorus as shown in Table 2.

TABLE 2.—THE MINERAL CONTENT OF EGGS
(Sherman, 1927)[1]

	Eggs	Egg yolk
Iron, milligrams per 100 g. fresh substance	3.0	8.6
Calcium, grams per 100 g. fresh substance	0.137	0.9
Phosphorus, grams per 100 g. edible substance	0.180	1.35
Iron, milligrams per 100 g. protein	22.0	53.0
Calcium, grams per 100 g. protein	0.5	0.9
Sulphur, grams per 100 g. protein	1.4	1.04
Phosphorus, grams per 100 g. protein	1.35	2.73

[1] SHERMAN, HENRY C., "Chemistry of Food and Nutrition." By permission of The Macmillan Company, publishers.

Vitamins in Eggs.—During recent years a mass of evidence has accumulated to demonstrate that foods for humans must contain other bodies not protein, nor fat, nor mineral, but of an organic nature and vitally important. They are called "vitamins" and eggs have been found to contain vitamins A, B and D, though they are deficient in vitamin C.

Vitamin A.—The first vitamin, A, is a substance necessary for growth and it is interesting to note that McCollum and Davis (1913) have shown "that the fats of eggs are fully comparable with butter fat as a source of vitamin A." Sherman (1927) says: "The relatively high concentration of this vitamin in the fat of milk and eggs at once suggests its importance in reproduction and in the development of the young." And the same author says further: "Milk is the most important source of vitamin A, with egg yolks and green vegetables as a meritorious second group. McCollum classes these three types (milk, eggs, and green vegetables) as 'protective foods' because of their richness in fat-soluble vitamin and in calcium—the two factors in which American dietaries are so often liable to be deficient because they consist too largely of the products of seeds, tubers, muscle meats, and sweets." Jones, Murphy and Moeller (1925) have demonstrated that eggs kept in a frozen condition for 9 years suffered little if any loss in vitamin A.

Vitamin B or F and G.—The second vitamin, B, prevents the development of a nerve disease in man called "beriberi" and McCollum and Simmonds (1925) say: "The high content of vitamin B stored in seeds and in eggs of birds and fishes suggests a due provision for the needs of the young during early life." In criticising the weakness of a vegetarian diet McCollum and Simmonds (1925) further say: "It is possible to make a satisfactory diet of foods derived entirely from vegetable sources, but it is not easy to do so. It would be difficult for man to eat enough leafy foods to enable him to succeed with a strictly vegetarian diet. Such a diet would generally be of low protein content. The addition of small amounts of meat will be valuable when such a regimen is adhered to. Eggs, because of their relative richness in vitamins A and B, will be often more effective supplements and the same may be said of small amounts of glandular organs." More recent investigations have shown that vitamin B is comprised of two separate vitamins, F and G, the former of which prevents polyneuritis while the latter prevents pellagra. Both are necessary from the standpoint of improving the diet.

FIG. 1.—Eggs are served in a variety of ways, including the proverbial soft-boiled, bacon and eggs, poached eggs on toast, the always popular omelette, in cakes, and in other ways in baking and cooking. "The egg is the cement of the baking industry." (*Photograph by U. S. Dept. Agr.*)

Vitamin C.—Vitamin C is known as the antiscorbutic vitamin because its presence in sufficient quantities in the human diet prevents scurvy from developing. Eggs apparently contain but very little if any vitamin C, the richest and most important sources of this vitamin being oranges, lemons, tomatoes, raw cabbage, apples, bananas, carrots and potatoes (Sherman 1927).

Vitamin D.—Vitamin D is known as the antirachitic vitamin because its presence in the ration in sufficient quantity prevents the development of rickets. Vitamin D is particularly important for growing children and for nursing mothers, as pointed out by Sherman (1927).[1] "In most respects, eggs may be regarded as intermediate between milk and meat, but the recent discovery that the egg yolk has special value for the prevention of rickets lends new significance to its inclusion in the dietaries of young children and nursing mothers." Hess and Weinstock (1927), in speaking of vitamin D as the antirachitic factor, make the following observations: "By far the most available source of this factor among the everyday foods is the egg, the yolk of which contains it in marked concentration. For this reason egg yolk has a particular value in the dietary of the infant and, it may be added, of the nursing mother." Table 3 gives the approximate amounts of vitamins A, B and D in a number of foods.

Vitamin E.—Vitamin E, often spoken of as the reproductive vitamin, is fairly widely distributed in different foods, particularly in seed embryos, but it is not known that eggs constitute an important source of this vitamin.

TABLE 3.—THE APPROXIMATE AMOUNTS OF VITAMINS A, B AND D IN A NUMBER OF FOODS

(Sherman, 1927)[1]

Food	Units of vitamin per pound of food		
	Vitamin A	Vitamin B	Vitamin D
Cod-liver oil	80,000 or more		Important amounts
Egg yolk	About 27,000	About 800	Important amounts
Spinach, fresh	About 25,000	300–400	Important amounts
Butter	8,000–22,000		Important amounts
Cheese, hard	About 10,000		
Eggs	About 9,000	About 260	
Milk, whole	About 1,000	About 150	Important amounts
Beef, lean	250	About 160	
Potatoes, baked	About 130	About 130	
Bacon	125 (?)		

[1] SHERMAN, HENRY C., "Chemistry of Food and Nutrition." By permission of The Macmillan Company, publishers.

Fuel Value of Eggs.—The fuel value of eggs is also an important factor. The number of calories per pound in chicken eggs is as follows: whole egg 670, egg white 230 and egg yolk 1,645.

Services Eggs Render.—It will be seen, therefore, that eggs are relatively rich in proteins, fats, minerals and vitamins, all of which are of particular importance in human nutrition. They also have a value from the standpoint of their fuel value. They fill an important role in a well-balanced diet of the adult and the minerals and vitamins serve a special function in the feeding of the young and the convalescent. In addition to the nutritive properties of eggs in the diet should be considered the popularity of eggs due to their qualities of taste and texture.

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[1] SHERMAN, HENRY C., "Chemistry of Food and Nutrition." By permission of The Macmillan Company, publishers.

Uses of Eggs.—"The ways of using eggs in the diet are almost limitless. They may form the main dish at breakfast or luncheon or enter as an ingredient into almost any complex dish at dinner from soup to the dessert course." (Jull *et al.* U. S. Dept. Agr. "Year Book, 1924.") They are served boiled, fried, shirred, scrambled and as a fluffy omelet. Eggs serve a far more important place in the baking and cooking industries than most people realize. In souffles, cakes and other baked products, eggs act as binders and as leavening agents. They also furnish "richness" to food, as in icings, sauces, candies, custards and cream fillings. In pastry the uses of eggs are manifold, and in salad dressings they are the common emulsifying agent.

"Their adaptability to a wide variety of uses, therefore, as well as their high nutritive value, makes eggs one of the most popular foods the world over." (Jull et al., 1924.)

EGG CONSUMPTION IN DIFFERENT COUNTRIES

The expansion of the poultry industry in every country depends upon the increase of egg consumption in the world at large and of the particular country concerned. Moreover, the annual per capita consumption of eggs in one country may serve to show to what extent per capita consumption in another country might be increased. Estimates of per capita consumption of eggs for various countries for 1926 are given in the following table, taken for the most part from the *Report on Egg Marketing in England and Wales* (1926).

Country	Eggs per Capita
Canada	313
Belgium	213
United States	204
France	133
Germany	117
Sweden	86
Denmark	75
Norway	61

From the best information available, it appears that the per capita consumption of eggs in the United States has not increased during recent years. Baker (1928) gives the following information: "The available data indicate that consumption per capita averaged about 17.1 doz. in 1899 and 16.9 doz. in the period 1922 to 1926, but that in 1927 it reached the highest point in the entire series of years, about 17.4 doz. The lowest consumption occurred, apparently, in the year 1919, when a figure 15.75 doz. is indicated."

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In the United States a comprehensive survey was conducted in 1923 among 8,650 farms located in all parts of the country with a view to determining the per capita consumption of eggs in the rural districts. Pirtle (1923) reports that on these farms the per capita consumption was 345 eggs, so that it is apparent that urban per capita consumption might be increased materially. In fact, in the Mountain and Pacific Coast states the per capita consumption was found to be 440 eggs used on the table and in baking. It would seem, therefore, that there is good reason to expect per capita consumption in the cities to increase, provided eggs of the highest possible quality only are placed upon the tables of the consumers and provided also that consumers become fully apprised of the dietetic value of eggs.

EGGS IN THE INDUSTRIES

Eggs enter into various industrial enterprises, the use for which apparently is on the increase. Eggs in the shell and dried or powdered eggs are used in the manufacture of ice cream, especially French ice cream. In Germany egg yolk is used in the manufacture of soap. Egg albumen is used in the manufacture of ivory. Considerable dried albumen and some dried yolk and mixed egg are also used in the arts. Liquid egg, yolk or albumen, treated with chemical preservatives, mainly boracic acid, is used somewhat. Albumen is used in pharmaceutical preparations and in the manufacture of paints and varnishes.

Other uses to which eggs, especially the albumen, are put include as a fixing agent for pigment colors, as an adhesive, as a sizing for paper, by bookbinders in gilding books, in photography, in making printer's ink, for thickening inks and in clarifying wines. Dried albumen is used for finishing glazed leather, in chrome tanning of skins and as a mechanical fixing agent in textile dyeing, particularly in printing delicate tints for which blood albumen is not suitable. Eggs in various forms are used in tanning and in the manufacture of glue. Egg-yolk oil is used for finishing glove leather and in bookbinding. Finally, bad eggs are sometimes incorporated in fertilizers.

POULTRY MEAT IN THE DIET

Among the animal products used for human food few have been longer or more widely known than poultry. While chickens and ducks contribute practically all of the eggs that are used in the diet, the kinds of poultry contributing chiefly as sources of poultry meat include chickens, turkeys, geese, ducks and guinea fowls. By far the largest proportion is supplied by chickens followed by the other kinds of poultry in the order named.

The percentage of edible meat obtained from live chickens compares favorably with that obtained from other kinds of live stock as shown in

Table 4 taken from Vernon (1924), the percentages for pork, beef and lamb having been obtained from Helser (1923).

TABLE 4.—PER CENT EDIBLE MEAT IN UNCOOKED CONDITION IN VARIOUS KINDS OF LIVE STOCK

(Helser, 1923)[1]

Kind of live stock	Per cent edible
Pork	75.75
Poultry	62.24
Beef	60.01
Lamb	53.80

[1] HELSER, M. D., "Farm Meats." By permission of The Macmillan Company, publishers.

The percentage of edible meat in the different classes of poultry varies somewhat. The percentage also varies in any one class, depending upon the kind, whether broilers or roasters for instance, and it varies in any one kind, depending largely upon the condition of fleshing. In Table 5, taken from Jull and Maw (1923*a*), is shown a comparison of the approximate dressed and edible percentages of various classes and kinds of poultry. The term "dressed" refers to the bleeding of poultry and removal of the feathers; the term "edible" includes the heart, liver, gizzard and the flesh, after the bones have been withdrawn.

TABLE 5.—COMPARISON OF THE APPROXIMATE DRESSED AND EDIBLE PERCENTAGES IN VARIOUS CLASSES OF POULTRY

(Jull and Maw, 1923*a*)

Class and kind	Per cent dressed, live weight	Per cent edible, dressed weight	Per cent edible, live weight
Unfattened broilers	88.00	54.00	48.00
Fattened broilers	91.00	61.00	55.00
Unfattened roasters	89.00	57.00	50.50
Fattened roasters	92.00	63.00	58.00
Fattened capons	92.00	67.00	62.00
Fattened fowl	92.00	64.00	59.00

In well-fattened cockerels averaging 4.64 lb. each, Maw (1921) found that the weight of the cooked drawn birds represented 53.50 per cent of the live weight and the weight of the cooked edible flesh represented 41.85 per cent of the live weight. The weight of the cooked edible flesh represented 46.90 per cent of the dressed weight and 58.03 per cent of the drawn weight. Vernon (1924) found that the percentage of cooked edible flesh was 46.93 per cent of the live weight of roasters averaging 5.05 lb. each; the percentage of cooked edible flesh was 52.55 per cent of the dressed weight and 64.32 per cent of the drawn weight.

TABLE 6.—AVERAGE COMPOSITION OF POULTRY AND POULTRY PRODUCTS
(Atwater, 1916)

	Refuse, per cent	Water, per cent	Protein, per cent	Fat, per cent	Carbohydrates, per cent	Ash, per cent	Fuel value, calories
CHICKENS							
Young:							
As purchased	18.8	55.5	17.8	7.2	...	0.9	615
Edible portion	....	68.4	21.9	8.9	...	1.1	760
Meat, not including giblets	....	66.9	22.6	10.1	...	1.1	820
Dark meat	....	70.1	20.8	8.2	...	1.2	710
Light meat	....	70.3	21.9	7.4	...	1.1	700
Meat, visible fat removed	....	74.5	21.8	2.5	...	1.1	500
Giblets	....	71.0	19.8	6.4	...	1.3	620
Liver	....	69.3	22.4	4.2	2.4	1.7	620
Heart	....	72.0	20.7	5.5	...	1.4	600
Gizzard	....	72.5	24.7	1.4	...	1.4	505
Broiler:							
As purchased	29.1	51.2	15.5	3.3	...	0.8	415
Edible portion	....	69.7	20.7	8.3	...	1.1	715
Meat, not including giblets	....	69.2	21.1	8.8	...	1.1	740
Giblets	....	72.8	18.7	6.1	...	1.3	590
Capon:							
As purchased	17.5	46.8	17.7	17.5	...	1.0	1,035
Edible portion	....	56.7	21.5	21.2	...	1.2	1,255
Meat, not including giblets	....	55.8	21.6	22.1	...	1.2	1,295
Giblets	....	63.3	20.5	14.6	...	1.3	970
Potted chicken	....	56.1	19.4	20.3	...	2.5	1,180
Canned chicken soup	....	87.1	2.9	3.3	5.1	1.6	280
Canned boned chicken	....	57.6	27.7	12.8	...	2.2	1,025

TABLE 7.—AVERAGE COMPOSITION OF EGGS AND SOME OTHER FOODS
(Atwater, 1916)

Kind of food	Refuse, per cent	Water, per cent	Protein, per cent	Fat, per cent	Carbohydrates, per cent	Ash, per cent	Fuel value, calories
Beef, sirloin steak, as purchased	12.8	54.0	16.5	16.1	....	0.9	955
Beef, brisket, as purchased	23.3	41.6	12.0	22.3	....	0.6	1,130
Lamb chops, as purchased	14.8	45.3	16.0	24.1	....	0.8	1,275
Mutton, leg, as purchased	18.4	51.2	15.1	14.7	....	0.8	875
Pork, chops, as purchased	19.7	41.8	13.4	24.2	....	0.8	1,230
Pork, salt fat, as purchased	11.2	17.6	7.4	59.6	....	5.1	2,565
Halibut, fresh, steaks, as purchased	17.7	61.9	15.3	4.4	....	0.9	460
Mackerel, salt, as purchased	19.7	34.8	13.9	21.2	....	10.4	1,115
Oysters, solid	....	88.3	6.0	1.3	3.3	1.1	220
Eggs, as purchased	11.2	65.5	11.9	9.3	....	0.9	595
Milk	....	87.0	3.3	4.0	5.0	0.7	315
Butter	....	11.0	1.0	85.0	....	3.0	3,490
Cheese, as purchased	....	34.2	25.9	33.7	2.4	3.8	1,890
Wheat flour	....	12.0	11.4	1.0	75.1	0.5	1,610
Wheat bread, white	....	35.6	9.3	1.2	52.7	1.2	1,175
Beans, dried	....	12.6	22.5	1.8	59.6	3.5	1,565
Potatoes, as purchased	20.0	62.6	1.8	0.1	14.7	0.8	305
Apples, as purchased	25.0	63.3	0.3	0.3	10.8	0.3	215

Nutritive Value of Poultry Meat.—From the standpoint of composition and nutritive value, poultry meat differs very little from other lean meats. It is an efficient protein food, since the proteins contain all the amino-acids needed for the building of body tissues. These proteins are also well assimilated by the human body. Like other meats, poultry is to be depended on for iron and phosphorus, but is low in calcium. The vitamin content probably varies markedly with the feed of the poultry. Hess and Weinstock (1927) make a very interesting observation concerning the vitamin D content of certain parts of the chicken. "Chicken liver and chicken fat have a high protective value, both the fat from the subcutaneous tissues as well as that from the region of the gizzard. In some experiments carried out with these fats it was found that they were even more potent than the liver."

The main difference in the composition of the edible portions of poultry lies in the fat content, its amount and distribution. Like other food animals, the younger birds are ordinarily less fat than the older ones; but the amount of fat, like the flavor and other qualities of the flesh, varies largely with the feed and exercise.

The tender meat of chicken or thoroughly cooked fowl is considered especially good for invalids and children, because, containing little fat and its fibers being rather loosely held together with connective tissue, it is easily digested.

Method of Preparing Poultry Meat.—The method of cooking poultry usually depends on the age and quality of the birds. Older ones need long slow cooking with water to make them tender. Younger birds may be roasted without preliminary cooking. This develops the desirable flavor due to browning, but does not soften the fibers so much as stewing. Very young birds may be quickly cooked by broiling directly over the fire or in a pan or by frying. Frequently in preparing poultry for the table other fat is added in cooking and serving, slices of bacon being laid over fowl to be roasted. Broilers are usually covered with butter or other fat before they are cooked. The popular dish known as "Maryland fried chicken" includes slices of crisp bacon, corn fritters and a cream gravy, all of them rich in fat. Cold chicken is often used in salad with a rich dressing or warmed up in a rich cream sauce.

The delicate flavor of chicken combines well with many others. For example, savory herbs, oysters, or chestnuts are used in stuffing and sweet peppers or mushrooms in sauces. By skilful blending of such flavors, poultry can be made the basis of a great variety of good dishes.

POULTRY MEAT CONSUMPTION

Information concerning the per capita consumption of poultry meat in various countries is not available and in the United States it has been estimated for rural sections only. Pirtle (1923) found that on 8,650 farms in various parts of the country, the per capita consumption of poultry (not classified) was 11.4 fowls. If these fowls averaged 4 lb. each in weight, which is regarded as a very conservative estimate for fowls consumed on farms, it would show an annual per capita consumption of approximately 45 lb. of fowl, or about 34 lb. of poultry meat in the "drawn" condition, which would be comparable to beef, pork and mutton as purchased on the market. The difference between 45 lb. live weight and 34 lb. dressed weight is accounted for by allowing approximately 24 per cent loss, as determined by Jull and Maw (1923*a*), due to blood, feathers and offal. Voorhies (1926) makes the following interesting observation: "The per capita consumption of poultry in rural districts is, from indications, eight to ten times that of industrial centers. Surveys of the United States Department of Agriculture indicated that the per capita consumption of poultry among 800 northern rural families was 45.4 lb., while for 150 southern rural families the consumption was 58.0 lb.

Voorhies (1926) makes reference to the best available data on the apparent per capita annual consumption of poultry in the various industrial centers of the United States based on investigations conducted by the U. S. Department of Labor in 1918 to 1919. It was found that the per capita consumption was 5.41 lb.

Regarding the per capita consumption of dressed chickens in the United States as a whole, Baker (1928) makes the following observation:

> Information on production and consumption of chickens and eggs is very unsatisfactory. The decennial census provides about all the data that exist prior to 1920. But on the basis of such information as exists it appears that the per capita consumption of chickens for meat has declined from about 20 lb. (dressed weight) in 1899 to about 18 lb. in the period 1922 to 1926. The lowest point, 16 lb., was reached in 1919 and the trend since then has been slowly upward.

The Bureau of Animal Industry of the U. S. Department of Agriculture reports the per capita consumption of various kinds of livestock meats for 1926 as follows:

	Pounds
Pork	65.7
Beef	63.4
Veal	8.2
Mutton and lamb	5.5

It will be observed that the consumption of pork exceeds all other kinds of meats and in addition it should be noted that the per capita consumption of lard for the same year was estimated to have been 13.5 lb.

Since the per capita consumption of poultry meat in the urban centers is undoubtedly much less than in rural sections, it is apparent that poultry meat consumption is considerably below that of pork and beef. The extent to which poultry meat consumption can be expected to increase will undoubtedly be determined to a considerable extent at least by the quality of the finished products as placed upon the tables of consumers.

CHAPTER II

THE POULTRY INDUSTRY

The very fact that today the domestic fowl takes rank in economic importance with the cow and the pig is evidence of its widespread popularity since early times.

Of the various classes of poultry, it is to be observed that chickens far outnumber all other classes and the service which chickens have rendered to humanity is related in an article by Jull (1927) on The Races of Domestic Fowl in which the term "fowl" is used synonymously with the term "chickens" in this book.

> From time immemorial, fowls have entered closely into human life, and in a variety of ways. They have made important contributions to the food supply of many nations and their feathers have served for the greater warmth and comfort of mankind. The pugnacious character of the wild cock led to the development of the sport of cockfighting, which frequently had a remarkable influence on civilizations of bygone days.
>
> From the aesthetic standpoint, various human races the world over have busily occupied themselves in evolving plumage colorations in bewildering variety, and have also produced changes in feather structure and body type that demonstrate the relative plasticity of the original stock.
>
> What man has accomplished within recent years by breeding from selected variants has been shown by his success in developing the large number of breeds and varieties of fowl known to us today. In these and in other ways, because of their small size as compared with many other domestic animals and because of their adaptability to a wide variety of climatic conditions, fowls have entered into the interests of more human beings than any other animal.

THE DEVELOPMENT OF THE POULTRY INDUSTRY IN THE UNITED STATES

The poultry industry of the United States has had a remarkable development, and a brief review will serve to show the various economic phases of development. By the time of the first settlements edible birds, domestic and wild, were largely classed together as "fowl." The plentifulness of wild fowl in the colonies undoubtedly detracted from the importance of domestic birds. Eggs were appreciated but were almost entirely a warm-weather product. There was slight commercial aspect to poultry keeping previous to 1825, most frequent mention of poultry products in the newspapers before that time being of feathers for beds and pillows. Between then and 1860 cheap grain in the inland districts and improved transportation encouraged egg production in the Ohio Valley.

In 1839 there were sixteen states with poultry valued at over $250,000 each. New York, with poultry valued at $1,153,413, Virginia and Pennsylvania had the largest numbers, although Ohio, Tennessee and Kentucky were only slightly lower in poultry value than Pennsylvania. Wisconsin and Iowa, the westernmost states listed, had $16,000 worth each.

Importations and Improved Breeding.—As the commercial aspect became dominant, poultry keepers saw the importance of increasing production per hen and in developing more economical methods of raising chickens. By 1840 or 1845 increasing attention was given to breeding, to feeding, and to other problems of management and to the introduction of new breeds. Asiatic fowls were first imported in important quantities shortly before 1850. Their popularity led to the first "hen fever" in the fifties, after which a rapid succession of breeds claimed attention. By 1849, when the New England poultry breeders and fanciers held their first poultry show, Cochin-Chinas, Shanghais and Plymouth Rocks had become well known. In 1847 two patents were issued on "methods of incubation," though it was 40 years later that the first practicable incubator was invented.

The egg market offered the main stimulus to improvement in the early history of the poultry industry. Not only were eggs more of a luxury than poultry in a land of abundant meat, but they withstood holding and transportation as meat and fowls could not. Consequently, many eggs were produced and prices ranged comparatively high. In 1863 egg shipments were reaching New York City from Ohio, Indiana, Illinois and Minnesota. During 1866 the city received 150,000 barrels of eggs, averaging over 70 doz. to the barrel.

Refrigeration and Transportation.—Marketing was limited by lack of means for preservation until the development of cold storage. Eggs were often preserved by immersion in limewater to seal the porous shell and, by 1870, were sometimes stored in fruit houses or ice houses. The last method displaced the others in the eighties and gradually changed to modern cold storage, which accelerated the increase in poultry during the eighties and nineties and has continued to lessen the seasonal variation in poultry and egg prices. In connection with the more costly storage and transportation coming into use, the displacement of the barrel by the 30-doz. egg case about 1880 was a considerable economy. The production of dressed poultry as well as of eggs was greatly stimulated by the demonstrated practicability of refrigeration for both transportation and storage.

During recent years five cities, New York, Chicago, Philadelphia, Boston and San Francisco, have required annually approximately over

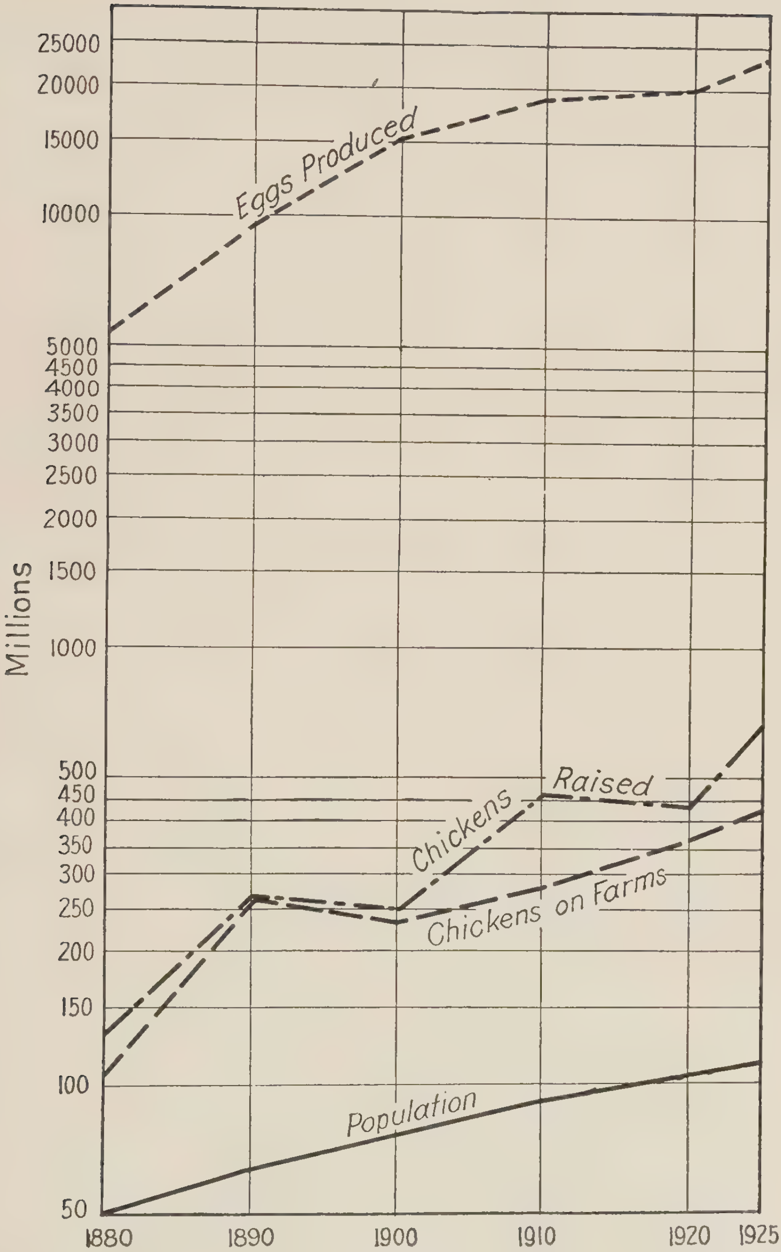

FIG. 2.—From 1880 to 1900 the number of poultry in this country increased much more rapidly than population, whereas the increase was relatively about the same from 1900 to 1920. The rate of increase in poultry was greater than for any other kind of livestock, but was most nearly approached by milk cows. This graph uses, for the years 1890 and 1920, corrected figures for the number of poultry on hand and not those reported by the Census Bureau. Corrections have been made to allow for difference in the time of taking the census. (*Voorhies*, 1926.)

500,000,000 doz. eggs and about 350,000,000 lb. of dressed poultry. The average daily requirements of the district served from New York City are now over 500,000 doz. eggs, about 450,000 lb. of dressed poultry and about 35 carloads of live poultry. There are now annually produced in the United States over 2,000,000,000 doz. eggs.

TABLE 8.—PRODUCTION OF EGGS, NUMBER OF CHICKENS RAISED AND ON HAND AND POPULATION OF THE UNITED STATES, WITH RATES OF INCREASE, CENSUS YEARS 1880, 1920 AND 1925[1]

(Pierce, 1926)

Year	Eggs produced,[2] thousands	Chickens raised,[2] thousands	Chickens on farms,[2] thousands	Population U. S., thousands	Index numbers, 1880 = 100			
					Eggs produced, per cent	Chickens raised, per cent	Chickens on farms, per cent	Population, U. S., per cent
1880, June 1	5,482,931	125,507	102,272	50,156	100.00	100.00	100.00	100.00
1890, June 1	9,836,675	285,609	258,871	62,948	179.41	227.56	253.12	125.50
1900, June 1	15,523,949	250,624	233,566	75,995	283.13	199.69	228.38	151.52
1910, Apr. 15	18,899,753	460,611	280,341	91,972	344.70	367.00	274.11	183.37
1920, Jan. 1	19,848,539	473,302	359,537	105,711	362.01	377.11	351.55	210.76
1925, Jan. 1[3]	21,958,942	545,848	409,291	112,786	400.50	434.91	400.20	224.87

[1] Compiled from annual reports of the Bureau of Census.
[2] Production figures are for the preceding year.
[3] Estimates by the Bureau of Agr. Economics, U. S. D. A.

THE VALUE OF THE POULTRY INDUSTRY

The value of the poultry industry may be considered from two aspects: (1) the place of poultry raising in American agriculture, and (2) the monetary value of the poultry industry itself.

Poultry Raising as a Branch of Agriculture.—Poultry raising occupies an important place in a well-balanced agriculture. According to the census of 1925, poultry was raised on 86.41 per cent of the farms in the United States, and on many farms poultry products were reported to be one of the best paying crops. In 1925 there were 58.52 per cent of the farms of the country keeping dairy cattle, 56.79 per cent keeping hogs, 32.36 per cent keeping beef cattle and 6.76 per cent keeping sheep. Poultry utilize enormous quantities of waste products, including grains and meat food, the value of which could hardly be utilized otherwise in as efficient a manner as in the production of eggs and poultry meat. Poultry are foragers and secure a part of their living from grass and other green food and insects. The raising of poultry utilizes labor and is a source of cash returns for practically every month of the year. Furthermore, eggs and poultry meat contribute an essential variety to the diet of the farm home table and, in addition, dispense with the necessity of providing for the table much meat food that would otherwise have to be purchased.

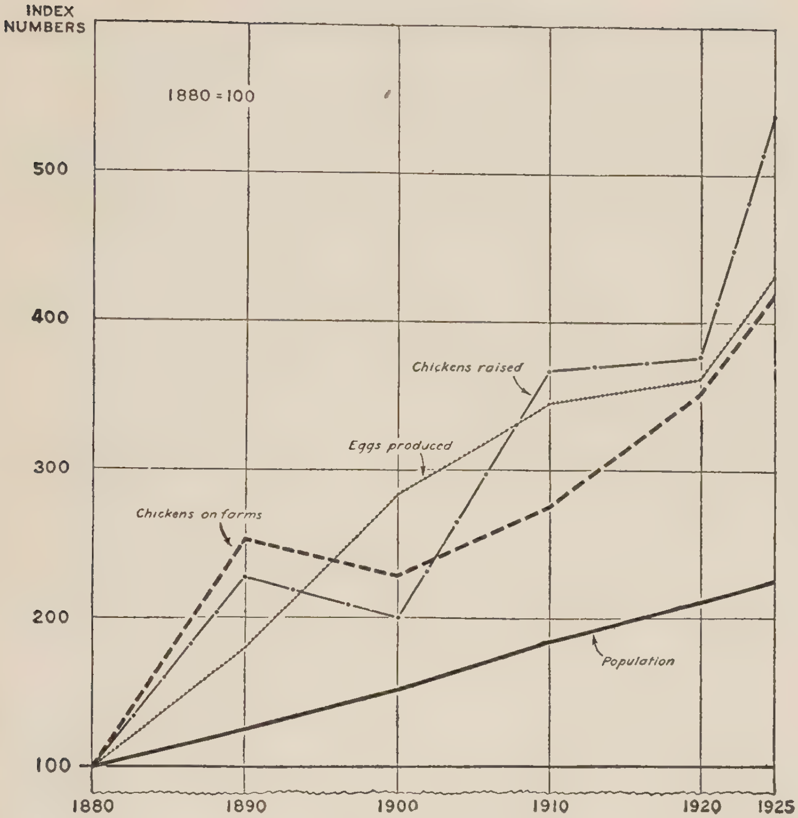

FIG. 3.—Comparison of increase in human population, chickens raised, and eggs produced in the United States, 1880 to 1924. (*U. S. Dept. Agr.*)

TABLE 9.—ESTIMATED GROSS FARM VALUE OF THE MORE IMPORTANT FARM PRODUCTS[1]

Product	Value in dollars, 1926	Per cent of total production
Dairy products	2,952,000,000	17.82
Corn	1,862,000,000	11.24
Swine	1,662,000,000	10.03
Hay and forage	1,490,000,000	8.99
Cotton	1,294,000,000	7.84
Poultry products	1,181,000,000	7.13
Cattle	1,081,000,000	6.53
Wheat	1,020,000,000	6.16
Fruits and fruit products	666,000,000	4.02
Potatoes	490,000,000	2.96
Sheep and wool	262,000,000	1.58
Tobacco	245,000,000	1.48
Horses	101,000,000	0.61
All other products	4,635,000,000	13.61
Total	16,566,000,000	100.00

[1] From *Crops and Markets*, U. S. Dept. Agr., vol. 4, No. 7, July, 1927.

Economic Importance of Industry.—From the monetary standpoint, the poultry industry compares favorably with many other important crops, as shown by the estimated value for 1926. The estimated values for some of the leading agricultural crops are given in Table 9.

The estimated value of poultry products increased from $1,117,000,000 in 1925 to $1,181,000,000 in 1926, and it must be remembered that the above valuations do not take into consideration many thousands of urban flocks.

Poultry in Relation to Other Classes of Live Stock.—Since poultry competes with other classes of live stock in producing foods of animal origin for human consumption, it is interesting to compare the relative standing of the various animal products in respect to the total value of the animal industry for 1926.

TABLE 10.—RELATIVE STANDING OF THE VARIOUS ANIMAL PRODUCTS IN RESPECT TO THE TOTAL VALUE OF THE ANIMAL INDUSTRY FOR 1926[1]

Product	Per Cent
Dairy products	40.3
Swine	22.8
Poultry	16.2
Cattle	14.8
Sheep and wool	3.6
Horses	1.4
Mules	0.5
Bees	0.2
Other animal products	0.2
Total	100.0

[1] From *Crops and Markets*, U. S. Dept. Agr., vol. 4, No. 7, July, 1927.

GEOGRAPHIC DISTRIBUTION OF POULTRY PRODUCTION

The United States can be divided into five fairly distinct sections according to their geographical location and the character of the industry.

Middle West Section.—The first section comprises principally the states lying in the Mississippi Valley, including Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Nebraska, Kansas, Missouri, Kentucky and Tennessee. This extensive grain and stock-raising section produces an enormous quantity of eggs and poultry meat, the feed cost of egg production being lower than elsewhere in this country. There are comparatively few specialized or commercial poultry farms; but the total poultry production is far in excess of the requirements for home consumption, so that a large proportion is marketed in the eastern consuming centers.

Northeastern Section.—The second section comprises the northeastern states, including New England, New York, Pennsylvania, New Jersey, Maryland and Delaware. In this section the poultry industry is one of major importance in agriculture, and many large and specialized poultry farms have been developed. At the same time, because of the very high proportion of the consuming population living in this section, the supply of poultry products from within the section is wholly inadequate to meet the demand, and large quantities of eggs and poultry meat are shipped in from other more extensive producing sections.

Pacific Coast Section.—The third section comprises the Pacific Coast states. In this section commercial poultry farming has been developed very extensively, and considerable quantities of eggs are shipped to the East annually.

Southeastern Section.—The fourth section comprises the southeastern group of states, a section where the poultry industry is relatively undeveloped. There is very little specialization and the farm flocks are small in size, so that production in several of these states frequently does not meet the local demand. The tardy development of agriculture as a whole and the general reliance upon cotton and tobacco as sources of farm income have been the major factors which have prevented the normal development of the poultry industry. These conditions are being remedied very rapidly, however, and at present poultry production is being greatly increased.

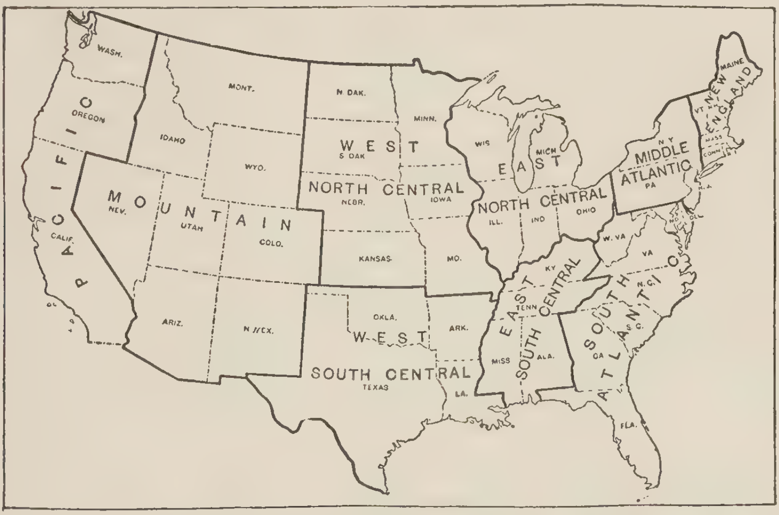
WASH.
OREGON
CALIF.
PACIFIC
MONT.
IDAHO
WYO.
NEV.
UTAH
COLO.
ARIZ.
N. MEX.
MOUNTAIN
N. DAK.
S. DAK.
NEBR.
KANSAS
MINN.
IOWA
MO.
WEST NORTH CENTRAL
OKLA.
ARK.
TEXAS
LA.
WEST SOUTH CENTRAL
WIS.
MICH.
ILL.
IND.
OHIO
EAST NORTH CENTRAL
KY.
TENN.
MISS.
ALA.
EAST SOUTH CENTRAL
N.Y.
PA.
N.J.
MIDDLE ATLANTIC
W. VA.
VA.
MD.
DEL.
N.C.
S.C.
GA.
FLA.
SOUTH ATLANTIC
MAINE
VT.
N.H.
MASS.
CONN.
R.I.
NEW ENGLAND

FIG. 4.—The United States is divided into nine geographic divisions or sections, which are used in reporting census data. (*U. S. Dept. Agr.*)

Southwestern Section.—The fifth section comprises the southwestern group of states, where the industry is made up largely of farm flocks of relatively limited size. Distance from the more important consuming centers has been a factor retarding development as compared with other sections.

TABLE 11.—NUMBERS OF CHICKENS ON FARMS, JAN. 1, 1925, BY GEOGRAPHIC DIVISIONS

Division	Number	Per cent
New England	8,138,168	1.99
Middle Atlantic	34,828,835	8.51
East North Central	89,622,590	21.90
West North Central	123,100,703	30.08
South Atlantic	41,120,216	10.05
East South Central	34,969,207	8.54
West South Central	43,835,263	10.71
Mountain	12,299,206	3.00
Pacific	21,376,661	5.22
Total	409,290,849	100.00

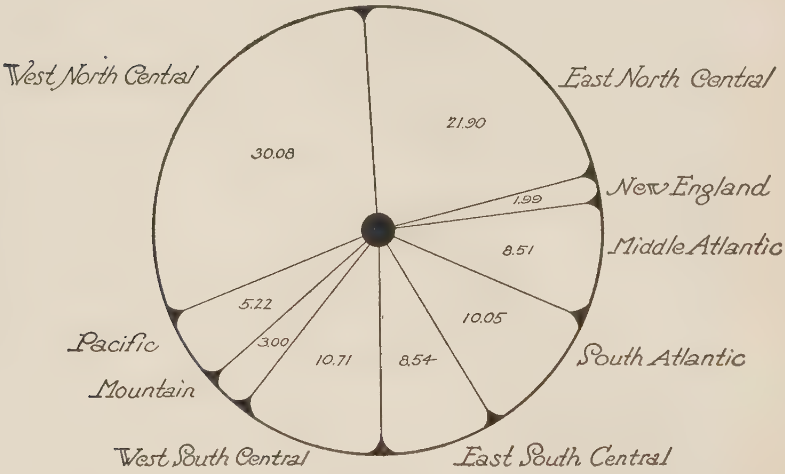

FIG. 5.—The poultry population of each of the nine geographic divisions as a per cent of the total poultry population of the United States. It is observed that the east north central and the west north central divisions, which include Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Nebraska, Iowa, Kansas, and Missouri, contain (21.90 + 30.08 = 51.98) over one-half of the country's total poultry.

TABLE 12.—NUMBER AND VALUE OF CHICKENS ON FARMS, JAN. 1, 1925, AND VALUE OF CHICKENS RAISED AND EGGS PRODUCED IN 1924, BY STATES[1]

State	No. chickens on farms, Jan. 1, 1925	Rank	Value of chickens on farms, Jan. 1, 1925	Rank	Value of chickens raised, 1924	Rank	Value of eggs produced, 1924	Rank
Alabama	6,284,460	23	$4,560,561	26	$5,370,724	25	$5,363,107	31
Arizona	635,877	46	649,274	45	581,794	47	1,324,935	44
Arkansas	7,164,091	21	4,894,688	24	5,554,988	24	6,457,999	26
California	12,784,512	14	12,557,940	12	12,808,329	14	31,615,277	7
Colorado	3,751,618	32	2,852,991	34	3,343,769	33	5,094,348	32
Connecticut	1,698,900	39	2,565,340	35	3,417,727	32	5,887,365	28
Delaware	1,365,032	41	1,733,591	39	1,582,186	40	2,360,929	43
Dist. of Col.	16,492	49	19,461	49	9,988	49	23,388	49
Florida	2,130,297	35	2,145,764	37	2,397,065	38	3,544,787	36
Georgia	7,043,403	22	5,395,105	22	7,359,621	20	5,709,027	30
Idaho	2,028,805	37	1,455,016	41	1,537,203	41	3,185,424	39
Illinois	25,738,132	3	25,416,933	3	27,560,014	2	32,285,697	6
Indiana	17,355,369	7	16,710,745	8	20,842,292	5	24,923,976	8
Iowa	30,275,338	1	29,143,910	1	30,448,956	1	34,841,094	4
Kansas	21,608,776	4	17,160,946	7	19,668,080	7	23,619,069	9
Kentucky	11,035,942	17	9,645,243	17	12,502,192	15	10,071,935	20
Louisiana	3,907,076	31	2,855,914	33	3,420,097	31	2,998,619	40
Maine	1,900,008	38	2,470,012	36	2,922,784	36	5,717,381	29
Maryland	4,198,305	29	4,697,526	25	5,597,445	23	6,945,803	25
Massachusetts	2,029,819	36	3,511,587	29	5,120,256	29	7,592,071	23
Michigan	12,578,979	15	12,962,306	11	12,934,751	12	20,604,319	11
Minnesota	16,408,080	9	13,319,488	10	13,867,950	11	20,955,638	10
Mississippi	5,787,879	24	4,447,456	27	5,349,902	26	4,525,286	34
Missouri	28,222,087	2	25,986,271	2	25,151,724	3	35,242,474	3
Montana	2,544,698	34	1,854,923	38	1,881,254	39	3,493,476	37
Nebraska	13,499,515	10	10,602,436	15	13,994,525	10	13,346,068	15
Nevada	225,300	48	208,812	48	245,443	48	518,937	48
New Hampshire	1,207,034	42	1,689,847	40	2,856,921	37	3,599,769	35
New Jersey	4,113,622	30	6,540,660	20	7,248,127	21	11,515,217	18
New Mexico	937,041	44	744,474	44	755,134	44	1,208,536	45
New York	13,408,720	11	17,349,790	6	15,432,527	8	33,020,981	5
North Carolina	8,558,145	19	7,184,101	19	10,337,442	19	7,783,439	22
North Dakota	5,181,246	26	3,373,206	30	3,173,437	34	4,869,964	33
Ohio	20,927,460	5	22,015,333	4	24,397,833	4	35,474,028	2
Oklahoma	13,023,482	12	10,721,973	14	12,876,328	13	12,707,030	16
Oregon	3,228,887	33	3,028,100	32	3,136,601	35	6,290,972	27
Pennsylvania	17,306,493	8	20,321,663	5	20,095,240	6	37,705,820	1
Rhode Island	361,393	47	610,755	47	726,894	46	1,205,591	46
South Carolina	4,238,254	28	3,340,665	31	5,140,671	28	3,277,540	38
South Dakota	7,905,661	20	6,045,301	21	7,003,365	22	8,786,213	21
Tennessee	11,860,926	16	9,665,002	16	10,531,788	18	11,067,127	19
Texas	19,740,614	6	13,798,172	9	14,968,166	9	18,937,104	12
Utah	1,366,873	40	933,600	43	933,074	43	2,518,304	42
Vermont	941,014	43	1,185,677	42	1,433,023	42	2,548,699	41
Virginia	9,220,882	18	8,971,965	18	11,829,989	16	11,631,573	17
Washington	5,363,262	25	4,997,042	23	5,222,093	27	13,920,080	14
West Virginia	4,349,406	27	4,164,255	28	4,245,643	30	6,975,982	24
Wisconsin	13,022,650	13	11,872,803	13	10,820,261	17	17,444,098	13
Wyoming	808,994	45	602,737	46	744,876	45	1,201,996	47
United States	409,290,849		379,011,450		419,380,528		571,938,492	

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[1] U. S. Census of Agriculture, 1925, Bur. Census, Dept. of Commerce.

TABLE 13.—THE RANK OF THE FIRST TEN STATES IN RESPECT TO NUMBER AND VALUE OF CHICKENS ON FARMS, JAN. 1, 1925, AND VALUE OF CHICKENS RAISED AND EGGS PRODUCED IN 1924

No. chickens on farms, Jan. 1, 1925	Value of chickens on farms, Jan. 1, 1925	Value of chickens raised, 1924	Value of eggs produced, 1924
Iowa	Iowa	Iowa	Pennsylvania
Missouri	Missouri	Illinois	Ohio
Illinois	Illinois	Missouri	Missouri
Kansas	Ohio	Ohio	Iowa
Ohio	Pennsylvania	Indiana	New York
Texas	New York	Pennsylvania	Illinois
Indiana	Kansas	Kansas	California
Pennsylvania	Indiana	New York	Indiana
Minnesota	Texas	Texas	Kansas
Nebraska	Minnesota	Nebraska	Minnesota

The rank of the first ten states in respect to the items given in Table 13 shows, in general, that in states near the eastern markets, such as Pennsylvania and Ohio, and in states where there is considerable specialization of the industry, such as in California and New York, there is either a higher egg production per bird or a higher price for eggs, or both. These four states all stand higher in rank in respect to value of eggs produced than they do with respect to any of the other items.

While the information in Tables 12 and 13 shows quite clearly that the states largest in size have the largest numbers of chickens per state and the greatest values of chickens raised and eggs produced annually, which is to be expected, the information does not show the relative size of the flocks per farm for the different states, nor the relative standing among the states concerning the average value of eggs produced and chickens raised per farm annually. Such information is highly desirable, however, if one is to obtain a correct impression concerning the relative status of the development of the poultry industry among the states. Table 14 gives this information.

The largest flocks per farm occur in states where the industry is specialized to a considerable extent, such as in New Jersey and California, and in those states lying in what is commonly referred to as the corn and wheat belts. The smallest flocks per farm occur in the southwestern and southeastern states.

The figures given for the average value of eggs produced and chickens raised are to be regarded as approximations only, though they are given for want of better information. However approximate the figures may be, they do show the relative standing of the states in respect to apparent revenue per farm from eggs and poultry.

TABLE 14.—AVERAGE NUMBER OF CHICKENS PER FARM, JAN. 1, 1925, AND AVERAGE VALUE OF EGGS PRODUCED AND CHICKENS RAISED IN 1924, BY STATES

State	Ave. no. of chickens per farm, Jan. 1, 1925[1]	State	Ave. val. of eggs produced & chickens raised per farm, 1924[1]
Dist. of Col.	223	New Jersey	$722
New Jersey	158	Rhode Island	566
Iowa	149	California	500
California	144	Massachusetts	489
Delaware	143	Connecticut	465
Kansas	141	Dist. of Col.	451
Illinois	121	New Hampshire	430
Missouri	119	Delaware	414
Nebraska	114	Washington	332
South Dakota	111	Iowa	322
Rhode Island	106	Pennsylvania	318
Minnesota	98	New York	303
Indiana	96	Kansas	283
Pennsylvania	95	Illinois	282
Maryland	94	Maryland	280
Ohio	93	Nevada	279
Washington	93	Ohio	267
Connecticut	85	Missouri	255
New York	84	Indiana	253
Arizona	83	Arizona	243
Nevada	82	Maine	232
New Hampshire	80	Nebraska	231
Massachusetts	78	South Dakota	221
North Dakota	77	Oregon	210
Colorado	76	Minnesota	207
Michigan	75	Michigan	200
Oklahoma	75	Vermont	180
Wisconsin	75	Utah	175
Oregon	72	Colorado	171
Utah	69	Wisconsin	162
Montana	67	Wyoming	161
Wyoming	67	Idaho	149
Idaho	64	Oklahoma	147
Tennessee	53	Montana	141
West Virginia	53	West Virginia	138
Texas	52	Virginia	134
Virginia	52	Florida	133
Maine	51	North Dakota	119
Kentucky	49	Kentucky	101
Florida	48	Tennessee	97
New Mexico	42	Texas	90
Vermont	42	New Mexico	89
Arkansas	39	North Carolina	74
Louisiana	36	Arkansas	65
North Carolina	35	Georgia	60
Georgia	33	Louisiana	59
Alabama	30	South Carolina	57
Mississippi	29	Alabama	52
South Carolina	29	Mississippi	49
United States	74	United States	180

From U. S. Census of Agriculture, 1925.

TABLE 15.—COMPARISON OF FARM VALUE OF CHICKEN EGGS PRODUCED AND OF CHICKENS RAISED IN 1924

	Value	Per cent
Eggs	$571,938,492	57.69
Chickens raised	419,380,528	42.31
Total	$991,319,020	

The data in Table 15 show that the value of eggs produced in 1924 exceeded by approximately 15 per cent the value of chickens raised in the same year. The same relationship has existed for a number of years.

TABLE 16.—NUMBER AND VALUE OF VARIOUS KINDS OF POULTRY ON FARMS IN THE UNITED STATES, 1920, THE LAST YEAR THAT CENSUS FIGURES ARE AVAILABLE FOR THE DIFFERENT KINDS OF POULTRY

Kind	Number	Per cent	Value	Per cent
Chickens	359,537,127	96.82	$349,508,867	93.74
Turkeys	3,627,028	0.98	12,904,989	3.46
Geese	2,939,203	0.79	5,428,806	1.46
Ducks	2,817,624	0.76	3,373,966	0.90
Guinea fowls	2,410,421	0.65	1,582,313	0.42
Ostriches	231	......	57,540	0.02
Total	371,331,634	100.00	$372,856,481	100.00

The data in Table 16 show that chickens represented about 97 per cent of the total poultry population in 1920, with turkeys, geese, ducks, guinea fowls and ostriches next in the order named. The same, relatively, applies concerning the value of the different kinds of poultry. The chicken, therefore, is by far the most significant in economic importance of all kinds of poultry.

CHAPTER III

THE CLASSIFICATION, ORIGIN AND EARLY DISTRIBUTION OF THE CHICKEN

In some respects birds are the most highly specialized of all animals. Many of the characteristics possessed by birds are adaptations for an aerial life.

> The non-conducting covering of feathers, the modification of the fore-limbs as wings, of the sternum and shoulder-girdle to serve as origins of the great wing muscles, and of the pelvic girdle and hind-limbs to enable them to support the entire weight of the body on land; the perfection of the respiratory system, producing a higher temperature than in any other animals; all of these are of the nature of adaptations to flight. Add to them the absence, in all existing birds, of teeth, the loss of the left aortic arch, and of the right ovary and oviduct, the specialized character of the brain, the poorly developed olfactory organs, and the extraordinarily large and perfect eyes, and we have a series of strongly-marked characteristics such as distinguish hardly any other class. (Parker and Haswell, 1897.)[1]

THE CLASSIFICATION OF THE CHICKEN

The position of birds in the animal kingdom shows clearly the degree of their specialized development. The animal kingdom is divided into various phyla (singular, phylum, from the Greek word meaning a tribe or race), such as a phylum of animals without backbones and another phylum of backboned animals.

Birds belong to the phylum Chordata, all animals belonging to which "possess an axial skeleton, the notochord lying between the nervous system and the alimentary tract; a central nervous system entirely on one side of the digestive canal, and gill slits extending from the pharynx to the exterior." Kingsley (1912).

One subphylum of the Chordata is the Vertebrata, the members of which have an axial skeleton, consisting of skull and vertebral column, which more or less completely replace the notochord. There are also many other distinguishing characteristics, including two kinds of appendages, a brain consisting of five parts and highly developed eyes and ears.

The subphylum Vertebrata is divided into a number of classes, such as fishes, reptiles, birds and mammals. Birds belong to the class Aves (from the Latin avis, meaning a bird), the members of which are distinguished by having feathers and by having a four-chambered heart.

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[1] PARKER and HASWELL, "A Text-book of Zoölogy." By permission of The Macmillan Company, publishers.

They are also warm blooded. All modern birds have no teeth and so they are placed in the subclass Neornithes.

Next in the classification of birds comes the superorder Neognathæ, which comprises all birds with a keeled sternum. In this superorder are included pheasants, chickens, turkeys, guineas, pigeons, ducks and geese.

Pheasants, chickens, turkeys and guineas all belong to the order Gallinæ. They have compact bodies and well-developed wings and legs, so that they can run and fly without excelling in either direction; the legs and toes are adapted for scratching and the hind toe is behind and elevated.

The Chicken Belongs to the Pheasant Family.—The suborder Galli includes birds which are cock-like and included in this suborder is the family Phasianidæ, the pheasants, which have tarsi with spurs.

The pheasants all belong to one family comprised of seven subfamilies. The chief distinguishing feature among four of the most closely related subfamilies is the manner of molting the tail feathers. In the first subfamily the molt of the tail is centrifugal, that is, the feathers molt in regular order from the center to the outside; in the second subfamily the tail molt is centripital; in the third subfamily the tail molt is from the third pair of feathers, outward and inward; in the fourth subfamily the tail molt is from the sixth pair outward.

In the fowl the tail molt is centripital in manner, so that the fowl belongs to the second subfamily, called Phasianinæ. There are several different pheasants belonging to this subfamily but the fowl is the only pheasant with a fleshy comb so that it is placed in a genus called Gallus, meaning a comb. (Jull, 1927.)

The biological classification taken largely from Parker and Haswell (1897), Kingsley (1912), Wetmore and Miller (1926), Beebe (1918) and Coues (1927) is as follows:

- Kingdom, animal as distinguished from the plant kingdom.
  - Phylum, chordata; axial skeleton with notochord.
    - Subphylum, vertebrata; skull and vertebral column replacing notochord.
      - Class, Aves; feathered, four-chambered heart, warm-blooded.
        - Subclass, Neornithes; without teeth.
          - Superorder, Neognathæ; keeled sternum.
            - Order, Gallinæ; Gallinaceous birds; fowls.
              - Suborder, Galli; cock-like.
                - Family, Phasianidæ; tarsi with spurs.
                  - Subfamily, Phasianinæ; centripital tail molt.
                    - Genus, Gallus; a comb.
                      - Species, domesticus; domestic chicken.

THE ORIGIN OF THE CHICKEN

The original habitat of the wild fowl, according to Beebe, is south and central India, the Himalayan terai, Assam, Burma, Ceylon, and throughout all the countries to the southward, on into Sumatra and Java with its string of lesser islands to the eastward.

The genus Gallus is comprised of four species: (1) Gallus gallus (Linnaeus) or Gallus bankiva, the Red Junglefowl; (2) Gallus lafayetti (Lesson), the Ceylon Junglefowl; (3) Gallus sonnerati (Temminck), the Grey Junglefowl; (4) Gallus varius (Griffith), the Javan Junglefowl. The Javan Junglefowl differs from the other three species in having a single-median wattle, a smooth-edged comb, truncated neck hackles and an extra pair of rectrices, or tail feathers.

The general distribution of these four species, according to Beebe, is as follows: The Red Junglefowl is widely distributed through eastern India, Burma, Siam and Sumatra; the Ceylon Junglefowl in Ceylon; the Grey Junglefowl in western and southern India; the Javan Junglefowl in Java and adjacent islands.

The eminent naturalist Darwin (1868), who made a close study of the possible origin of the domestic fowl, concluded that our domestic stocks were all derived from one species, the Red Junglefowl. Since Darwin's time, the great majority of the naturalists have agreed with his opinion. Even as late as 1918, Beebe, in his exhaustive study of the wild fowl, stated definitely that "There is no doubt that the Red Junglefowl alone is the direct ancestor of all of our domestic poultry, so this question is removed from the discussion." Houwink (1911) is inclined to the same viewpoint.

The principal reasons why Darwin regarded the Red Junglefowl as the progenitor of all our domestic breeds of poultry was because he observed that it resembled some of the early domestic breeds more closely than the other three species, its voice was more similar to the voice of the domestic fowl, and when mated with domestic stock produced offspring more freely, and the offspring were much more apt to be fertile than hybrid offspring from any of the other species.

It is very interesting to note that Beddard (1898) has recorded striking differences in the lengths of the intestines of Red Junglefowl, Gallus bankiva, and the Grey Junglefowl, Gallus sonnerati. In bankiva the length of the small intestine is given as 61 in., the large intestine 5, and the caeca 6.25, while in sonnerati the same organs measure 35, 2.5 and 4 in., respectively.

Beebe states that all four species will cross with one another and that the hybrids are more or less fertile among themselves. Many references are cited where crossing has taken place among the four wild species and domestic stocks. The matings sometimes occurred naturally and sometimes the natives encouraged crossing. This was done by trussing and pinning a domestic hen to the ground and after exciting a cock by holding a wild hen near him he is placed on the domestic hen; another method is to have the three birds each in a separate cage and after exciting the cock by placing the cage containing the wild hen near his cage it is suddenly substituted for the cage containing the domestic hen.

Tegetmeier (1873), a coworker with Darwin, finally arrived at a different conclusion from that of Darwin concerning the origin of all of our domestic fowl. Tegetmeier pointed out that numerous hybrids were obtained from crossings between domestic stocks and the Ceylon and Javan Junglefowls. He further held: "I have no doubt in my own mind that the wild Galli have intermixed in not a few instances, and perhaps through not a few centuries, in producing our domestic breeds." Tegetmeier was especially doubtful of the Asiatic races of domestic fowl, Brahma, Cochin and Langshan, being derived from the Red Junglefowl. Rather he believed that they descended from a readily domesticated, short-winged species that probably originated from the same ancestral stock that originally gave rise to the four wild species referred to above.

More recently, Lotsy and Kuipper, in Holland, quoted by Punnett (1923), conducted experiments in crossing representatives of the four wild species with domestic stocks, the results of which give added evidence to the production of fertile hybrids in all the matings. Fertile offspring between Gallus sonnerati and domestic fowls have also been raised by Ghigi (1916).

Furthermore, Punnett (1923)[1] refers to a second generation hybrid bird from a cross between the Red Junglefowl, *Gallus bankiva*, and the Javan Junglefowl, Gallus varius, the hybrid being black in color. Regarding the significance of the appearance of this black hybrid, Punnett makes an interesting observation.

> Black we know to be dominant to black-red, and the occurrence of such a bird, produced as this was, suggests that some at any rate of the characters of domestic fowls, which are dominant to those of Gallus bankiva, may owe their origin to one of the other wild species of Gallus. In this particular instance we may suppose that the factor for black has come from Gallus varius. In Gallus varius itself its manifestation is obscured by a deep green beetling effect, because other factors come into play. But when the black factor alone is transferred on to a red-black substratum we may expect to get a bird which is almost or fully black. It is not impossible that other plumage characters such as pencilling, spangling, etc., have arisen in a similar way.
>
> Punnett suggests, therefore, the importance of . . . a skilful and systematic study of the results derived from crossing the four wild species of Gallus, both with one another and with domestic races. Until this has been done there can be no certainty as to the manner in which our various races of poultry have arisen, and any further discussion as to their origin is merely a waste of time.

THE EARLY INFLUENCE OF COCKFIGHTING

That the sport of cockfighting exercised a tremendous influence not only in the domestication of wild birds but also in the subsequent distribution of the fowl is amply demonstrated by the importance attached to the pastime by many human races. The literature of various nations contains many references to the sport, and Edward Brown (1906), who has given much thought to the question, has concluded as follows: "From the evidence which has come to us it would appear that the sport of cockfighting has as much responsibility for the domestication of the fowl as demand for food, and that, when once it was brought into the service of man, sport was chiefly instrumental in making the species popular."

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[1] PUNNETT, R. C., "Heredity in Poultry." By permission of Macmillan & Co., Ltd., London, publishers.

THE EARLY DISTRIBUTION OF THE CHICKEN

The following excellent account of the early distribution of the domestic chicken is taken largely from Beebe (1918). The domestication of the cock in China dates back to as early as 1400 B.C., although the chicken appears in the hieroglyphics in the tomb of Mera about 3200 B.C. The modern name for the bird, ki or kai, can be traced to the Chou Dynasty, which extended from 1122 to 249 B.C. Ki is defined in a very ancient dictionary as "the domestic animal which knows the time," and in a glossary of the time of Confucius, it is found again.

In India, in the Indus period of the Aryan invasion, the time of the Rig Veda, there is no mention of the cock, but about 1000 B.C., when the Aryans had reached the Ganges, in the Atharua and the Yajur Vedas, the cock was well known.

The cock moved nothward and westward, against the line of Aryan invasion, and reached Bactria and Persia at a very early date. Judging by the part which the cock played in Persian religion and mythology, and the frequent reference to it in Zoroastrian literature, its advent must have antedated considerably 600 B.C.

In Grecian literature the first mention of the cock is by Theognia about 525 B.C. On the other hand, the image of the cock appeared on coins from the temple of Artemis at Ephesus at least 700 B.C.

Subsequent distribution of the fowl followed the line of the Iranian invasion, which carried the bird through Bactria and Persia on into Scythia and Europe, stretching across finally to the British Isles and spreading down from Gaul into central Italy. Beebe says that long before Greek colonists carried the bird to south Italy, it had passed on to the northward and was being carried southward through Italy on the line of an independent advance. The first European distribution of the cock was overland rather than by sea or by coastal colonists. The Romans found it well established in Gaul, England and among the Germans.

The distribution of the fowl southward began when the Greeks carried stocks southward to the Phoenician cities. Only at a late date, however, did the fowl become well established on the Syrian mainland. From the Medes and Persians, to whom it had been known since 1000 B.C., it was taken to the Assyrians and Babylonians as early as 700 B.C. From the Arameans it was introduced to the Jews in Palestine about 200 B.C.

By the time of the Christian era it seems highly probable that the domestic fowl had spread itself over the western parts of Asia and the eastern parts of Europe. From these parts domestic fowls were readily transported to other countries including South Africa, Australia, Japan, Siberia, Russia, and Scandinavian countries and the Americas.

CHAPTER IV

THE BREEDS OF CHICKENS

During the first half of the seventeenth century several importations of domestic fowl were made from England, various parts of Europe and Asia. Interest in the breeding of poultry increased, and definite attempts were made to develop standards of excellence for the various breeds of chickens that were then being bred. In 1849 the first poultry show was held in America, and this gave an impetus in the development of established standards for the various breeds.

First Standard of Perfection.—Interest in the breeding of the various classes of poultry for exhibition purposes increased rapidly, until by 1873 there took place the first organized effort to place the breeding industry upon a stable basis. In that year there was organized the American Poultry Association, which had for its object the formulation and adoption of a standard of excellence to be used exclusively by poultry associations in awarding prizes on exhibition poultry. A complete standard was adopted for all the then recognized varieties of domestic and ornamental classes of poultry, and in 1874 the first Standard of Perfection was printed, Since that time, the Standard, revised periodically, has served as the basis of guidance in breeding operations in developing many breeds and varieties. In many respects, therefore, the standard-bred poultry industry served as a foundation for the subsequent development of the industry. Poultry exhibitions have exercised a remarkable influence in maintaining high standards of excellence and in fostering the interests of the industry.

Relative Value of the Chicken.—The majority of the breeds possess egg-laying and meat-producing qualities and many of them also possess beautiful combinations of color patterns that give chickens a very important place in animal breeding. Then, again, the relatively small size of chickens, as compared with cattle, sheep and hogs, makes them particularly adaptable to a wide variety of conditions. These factors account in a large measure for the great number of breeds and varieties that exist and for the variation in type, color and color patterns.

Numerous Breeds and Varieties.—The breeds and varieties of chickens are so numerous that a detailed discussion of all the characters they possess is not possible in this book. Moreover, the reader is referred to the "American Standard of Perfection" published by the American Poultry Association (1930), and to the works of Weir, Johnson and Brown

(1904), Wright (1911), Platt (1921), Robinson (1924 and 1925) and Jull (1926*a* and 1926*b*).

The breeds are classified largely from the standpoint of their origin, emphasis being placed upon the more important characteristics of economic importance in the more popular breeds and upon the unusual characteristics of those breeds and varieties bred largely for pleasure.

Significance of Type.—The distinguishing feature whereby one breed of fowls differs from another breed is in respect to type, although this is rather a confusing situation inasmuch as the visible body type is influenced not only by the actual shape of the body but also by the feather contour. In breeding standard-bred poultry, the "type" of a bird, as determined by feather contour, has been regarded as of greatest importance, so much that in many cases the actual body type has received minor attention. The situation has developed so that it is now recognized that "shape makes the breed," shape here indicating very largely feather contour.

Variety Colors.—Within each breed of fowls there naturally was a tendency to segregate various color combinations or, where only one color existed in the original breed, there was a tendency to develop new color patterns. In either case, it was necessary to adhere to the original type or shape characteristic of the breed, and thus it has arisen that varieties of a breed are supposed to be identical in all characteristics except plumage color or, in some cases, in respect to the shape of comb, standard weight, color of shanks and other minor characteristics. There is a large grain of truth in the old saying of poultry breeders that "shape makes the breed and color the variety."

The illustrations in the accompanying pages are designed to present the standard type of the various breeds and should be studied closely. The problem of an adequate color description for the numerous varieties is simplified materially, because there are relatively few standard color patterns. For instance, the color patterns of the Dark Brahma, Silver Penciled Plymouth Rock and Silver Penciled Wyandotte are almost identical. So also in the case of the color patterns of the Light Brahma, Columbian Plymouth Rock and Columbian Wyandotte. The plumage pattern and feather markings of the Partridge Cochin are identical with those of the Partridge Plymouth Rock and Partridge Wyandotte. There are black varieties and white ones of many breeds and there are blue varieties of a few breeds, in each case the color being identical.

AMERICAN BREEDS

A number of breeds have been developed in America to meet the market demand for a bird with a yellow skin, clean shanks and adapted to the conditions of the country. All birds belonging to the American class are spoken of as being "clean legged"; that is, they have shanks free from feathers. They also have yellow shanks and skin, except Java, and Jersey Black Giant which have yellow skins but black shanks. All have red earlobes and lay brown-shelled eggs and are classed as broody.

Dominique.—From the best records available, it appears that purely barred chickens of relatively small size and usually with rose combs were common in many parts of the eastern United States as early as 1750. Interest in poultry breeding increased and more attention was given to the improvement of these barred chickens until they came to possess a fair degree of uniformity in type and were more or less the same size. They were recognized under the breed name "Dominique" but their popularity soon waned.

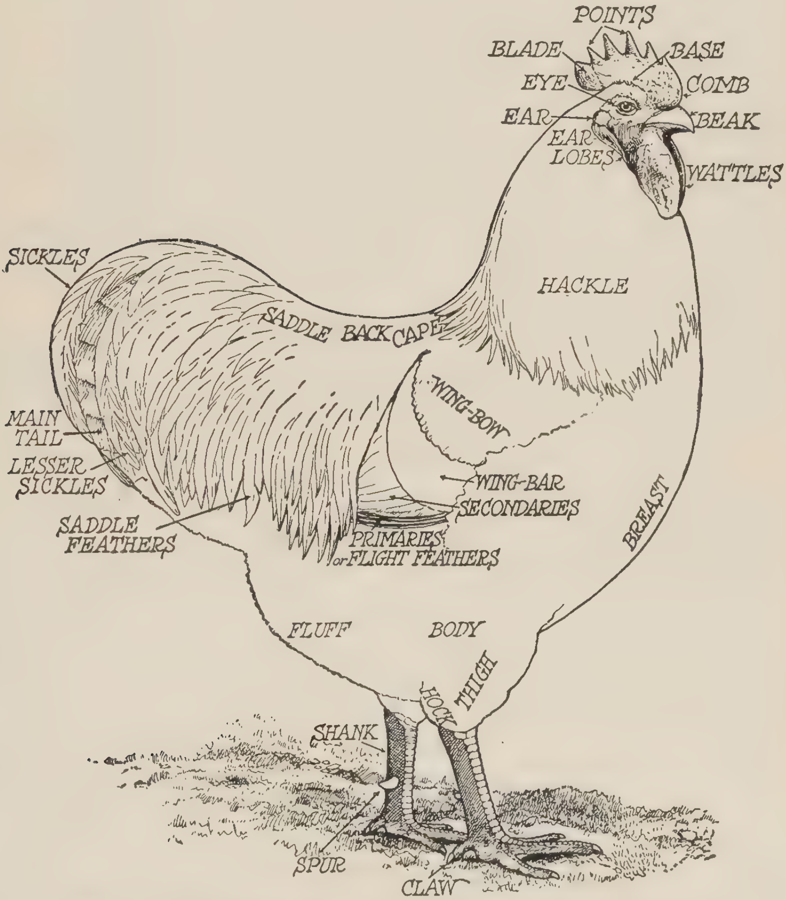

POINTS
BLADE
BASE
EYE
COMB
EAR
BEAK
EAR LOBES
WATTLES
SICKLES
HACKLE
SADDLE
BACK
CAPE
WING-BOW
MAIN TAIL
LESSER SICKLES
WING-BAR
SECONDARIES
SADDLE FEATHERS
BREAST
PRIMARIES or FLIGHT FEATHERS
FLUFF
BODY
THIGH
HOCK
SHANK
SPUR
CLAW

Fig. 6.—Glossary chart giving the names of the different parts of the male fowl. (*U. S. Dept. Agr.*)

In plumage color the Dominique has a generally bluish or slaty cast; the feathers in all sections are barred with alternate, rather irregular light and dark bars. The markings lack the clean-cut effect of the Barred Plymouth Rock barring. The comb is rose. The standard weights, in pounds, are: cock, 7; hen, 5; cockerel, 6; pullet, 4.

Plymouth Rock.—The Plymouth Rock is one of the most popular breeds in America, largely because it is a bird of good size, with excellent fleshing properties and good egg-laying abilities. The birds belonging to this breed are rather long bodied, fairly broad, with fairly prominent breast and good depth of body. This breed has a single comb. The standard weights, in pounds, are: cock, 9½; hen, 7½; cockerel, 8; pullet, 6.

The Barred Plymouth Rock seems to have been developed from at least three fairly distinct strains, although Robinson (1924), a leading American authority on the origin of the American breeds and varieties, has stated that the Barred Plymouth Rock owes much of its history to the Dominique.

According to Robinson, three distinct strains enter into the development of the improved Barred Plymouth Rock. The Drake strain was originated about 1866 at Stoughton, Mass., the original stock probably being single-comb barred birds. The Sussex County strain was also developed in Massachusetts, going as far back as 1856. The Upham, or, as Robinson says, Spaulding-Upham, strain was developed in Connecticut about 1865 or 1866. These three strains were developed independently of one another. In some of the strains what some writers refer to as "hawk" colored birds being used undoubtedly were Dominiques. Cochins and Dorkings were the two breeds used to a greater extent than any others, and Robinson maintains that the early Plymouth Rocks were of pronounced Dorking type.

The Plymouth Rock, as it was then called, enjoyed wide popularity, which has increased steadily from that time. The plumage color is grayish white, each feather crossed by almost black bars which should be even in width, straight and should extend down to the skin. Each feather should end with a narrow, dark tip, which with the alternate dark and light bars gives a bluish cast or shade to the surface color. The barring in the hackle and saddle of the male is narrower than in other sections. Solid black or partly black feathers may occur in some birds of practically all strains in this variety, but their appearance does not necessarily indicate impurity of breeding. Black spots on the shanks are also common, particularly in females, but they do not indicate impurity of breeding.

In the breeding of Barred Plymouth Rocks there is a decided tendency for the males to come lighter in color than the females, and for this reason many breeders resort to two separate matings, one for the production of males of standard color and the other for the production of females of standard color. This system of breeding is known as "double mating." To produce males of standard color, a standard-colored sire is mated to medium-dark dams, or dams two or three shades darker than females of standard color. This mating is known as the "cockerel mating." To produce females of standard color, dams of standard color are mated to a medium-light sire or one that is two or three shades lighter than males of standard color. This mating is known as the "pullet mating."

The White Plymouth Rock originated as a "sport" from the barred variety. It is quite possible, however, that other strains of White Plymouth Rocks were developed from crosses of White Dorkings and White Cochins, and it is also possible that White Dorkings were crossed with Barred Plymouth Rocks, and then the white color factor extracted from subsequent generations. The plumage color is pure white throughout and should be free from black ticking, brassiness and creaminess.

The Buff Plymouth Rock was developed in an entirely different manner from the Barred variety and apparently has no relation to it. Two strains of Buff Plymouth Rocks were originated about 1890, one strain being developed from single-comb Rhode Island Reds which were common in Rhode Island at that time, although not recognized under that name; the other strain was developed from crosses of White Plymouth Rocks and Buff Cochins. The plumage color is golden buff in all parts of the surface color, and all sections should be of the same shade. The presence of feathers having a shaft of different color from the rest of the feather and the presence of feathers sprinkled with lighter color are of common occurrence but are undesirable. The undercolor is of little lighter shade than the surface color.

The Silver Penciled Plymouth Rock owes its feather markings, to a considerable extent, to the Dark Brahma. It has a distinctive color pattern in which the male differs considerably from the female.

The plumage of the male consists of a silvery white surface color, extending over the wing bows and back, and the hackle and saddle are silvery white, striped with black. The rest of the plumage, including the main tail feathers and sickles, is black. The primaries are black, except for a narrow edging of white on the lower edges of the lower webs, and the secondaries are also black, with some white.

In the female the general surface color is gray, with a distinct, concentric penciling of dark gray on each feather. The neck feathers are silvery white, with a black center showing a slight gray penciling, and the main tail feathers are black, with the two top feathers showing some penciling. In both sexes the undercolor is slate, shading to a lighter color toward the base in the male.

The Partridge Plymouth Rock, developed apparently from Partridge Cochin and Brown Leghorns, in color pattern is practically the same as the Silver Penciled Plymouth Rock, except that the white in the Silver Penciled is replaced by red or reddish brown.

The hackle of the male is greenish black with a narrow edging of brilliant red; the plumage in front of the neck is black. The wing bow is brilliant red. The primaries are black, with the lower edges reddish bay, and the secondaries are also black, the outside web of reddish bay with greenish black at the end of each feather. The back has brilliant red feathers, each with a greenish-black stripe down the middle.

In the female the neck is reddish bay and the front of the neck and breast are both deep reddish bay, distinctly penciled with black. The wing bows are also deep bay penciled with black. The primaries are black with an edging of deep reddish bay on the outer webs, the inner webs of the secondaries are black, and the outer webs are reddish bay deeply penciled with black. The back is also deep reddish bay penciled with black. The undercolor of all sections of both sexes should be slate. The beak is dark horn shading to yellow at the tip.

The Columbian Plymouth Rock was developed from crosses between Light Brahmas and White Plymouth Rocks. Most of the plumage is white, although the hackle feathers of the male and the neck feathers of the female and the tail coverts of both sexes are black, with a distinct white lacing. The tail feathers in both sexes are black. The wings also carry some black on the primary and secondary feathers, which is almost hidden when the wings are folded. The undercolor of all sections in both sexes should be light bluish slate.

The Blue Plymouth Rock was first recognized as a standard variety in 1919. In the male the plumage color over practically all parts is a medium shade of slaty blue, each feather laced with darker blue and in the wing bows, hackle, back, saddle, sickle feathers, and tail coverts the lacing is very dark. This gives the surface color of the upper sections of the male a very dark appearance. In the female the general plumage color is a slaty blue of even shade, each feather except the primaries having a well-defined, narrow lacing of darker blue. The neck is decidedly darker than the rest of the body color. Both sexes have a slaty blue undercolor.

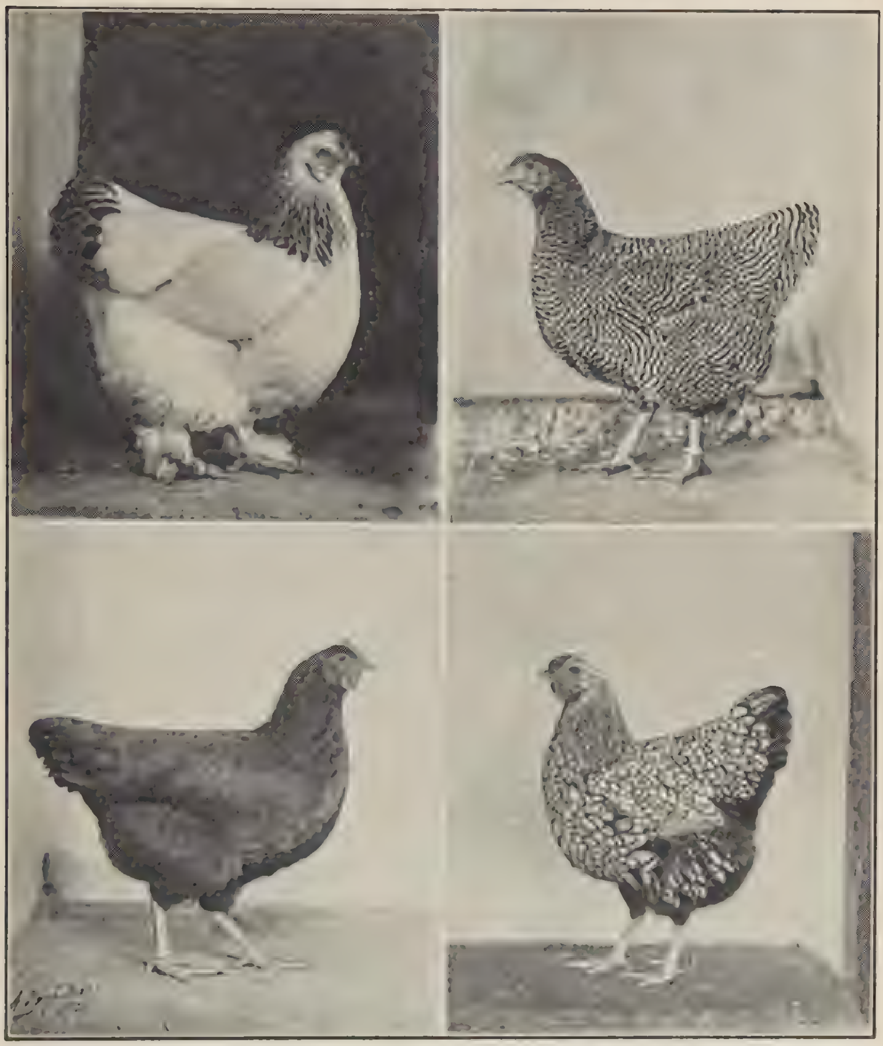
Wyandotte.—The body of the Wyandotte is comparatively round and the general shape and character of feathering give it an appearance of having a rather short back and being low set. Like the Plymouth Rock, it is a good general-purpose breed, well adapted for flesh production and a good layer when bred for egg production.

All Wyandottes have rose combs. The standard weights, in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet, 5½.

The Silver Laced Wyandotte was the first variety developed, about 1860, principally from crosses between Buff Cochins and Silver Sebright Bantams and from crosses between Dark Brahmas and Silver Spangled

Hamburgs. This variety has a striking color combination which makes it very attractive.

The male has a silvery white hackle, back and saddle, the hackle and saddle feathers being striped with black. The feathers of the body and breast are white, laced with a black edge. The primaries are black with the lower edges white; the secondaries are also black with the lower half of the outer webs white and the upper webs edged with white. The main tail feathers are black.



Light Brahma. Barred Plymouth Rock.
S. C. Rhode Island Red. Silver Laced Wyandotte.

Fig. 7.

The female has white feathers laced with black over the entire body, except the neck feathers, which are black; there is also some black in the wings. The primaries and secondaries are practically the same as in the male. In both sexes the undercolor is slate, in the male shading to lighter slate at the base of the feathers.

The White Wyandotte originated as a "sport" of the Silver Laced variety and is white throughout and, like the White Plymouth Rock, should be free from any brassiness or creaminess or black ticking.

The Buff Wyandotte was developed about 1890 by mating Golden and White Wyandottes with Buff Cochins, from Hamburg and Cochin crosses and from fowls which were common in Rhode Island. The plumage color is an even shade of buff throughout, identical with that of the Buff Plymouth Rock.

The Golden Laced Wyandotte was developed from crosses in which the Silver Laced Wyandotte, the single- and rose-comb Brown Leghorn and the Buff and Partridge Cochin were used. The Golden Laced Wyandotte has the same general color scheme as the Silver Laced variety, except that the white is replaced with red and reddish brown. The undercolor is slate, in the male shading to red at the base.

The Partridge Wyandotte originated between 1890 and 1896 from crosses between Golden Laced Wyandottes and Golden Penciled Hamburgs and from mixtures of Golden Laced Wyandottes, Cornish, Brown Leghorn and Buff and Partridge Cochin. It has the same color pattern as the Partridge Plymouth Rock.

The Silver Penciled Wyandotte was developed from the Dark Brahma, with its penciling, and Silver Penciled Hamburgs and Partridge and Silver Laced Wyandottes. It has the same color pattern as the Silver Penciled Plymouth Rock.

The Columbian Wyandotte appears to have been developed from matings between Light Brahmas and other breeds. It has the same color pattern as the Columbian Plymouth Rock.

The Black Wyandotte appeared about 1885 as a black "sport" of the Silver Laced variety. It is black in all sections, showing a greenish sheen, free from purple barring. The undercolor is slate.

Rhode Island Red.—The Rhode Island Red has a rather long, rectangular body and appears somewhat more upstanding than the Plymouth Rock or the Wyandotte. At the same time, the body has good depth, is wide and of good length, making a good meat-producing bird. By proper breeding methods this breed can be developed into excellent layers. There are two varieties, single comb and rose comb, which are otherwise identical. The standard weights, in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet 5½.

This breed was developed in the first quarter of the nineteenth century from matings of Red Malay game cocks to the common hens of Rhode

Island and from matings between rose-comb Brown Leghorns and mottled females.

The plumage color of the Rhode Island Red is a rich brownish red, which should be as even as possible over the entire surface and throughout all sections, except that the lower webs of the primaries are mostly black, the upper webs of the secondaries are partly black, and the tail coverts, sickle feathers and main tail feathers are black. In the lower neck feathers of the female there is also a slight ticking of black. The under-color of all sections in both sexes should be red and free from a dark or slaty appearance, which is known as "smut." The beak is reddish horn and the shanks and toes are rich yellow or reddish horn.

Rhode Island White.—The Rhode Island White, of which the rose comb is the only variety, is identical in size and type with the rose-comb Rhode Island Red and was developed from White Wyandottes, Partridge Cochins and rose-comb White Leghorns. The plumage should be pure white, free from any tint of brassiness.

Jersey Black Giant.—The Jersey Black Giant, developed largely from Asiatic sources, is the largest of the American breeds. It resembles the other American breeds in most of their characteristics, although it has not been bred so extensively for egg production. It resembles the Plymouth Rock in type but is broader, deeper and longer. The comb is single. The standard weights, in pounds, are: cock, 13; hen, 10; cockerel, 11; pullet, 8.

The plumage in all sections is black with a greenish sheen. The undercolor is slate, approaching white at the skin. The beak is black, shading to yellow toward the tip. The shanks are black with yellow on the under surface of the feet and toes.

Java.—The Java originated from the Black Cochin used on the common fowls of the country in the early history of the American poultry industry. It is a bird of good size, having a long and deep body with good width of back and a full, well-rounded breast. The comb is single. The standard weights, in pounds, are: cock, 9½; hen, 7½; cockerel, 8; pullet, 6½.

The Black Java is black throughout, with a greenish sheen on the surface plumage. Any tendency toward purple barring is undesirable. The undercolor is dull black. The beak is black and the shanks and toes are black or nearly black, shading to willow, and the bottom of the feet and toes should be yellow.

The Mottled Java, which is claimed to have been developed from the Plymouth Rock, has black plumage mottled with white throughout, the black more plentiful than the white. The undercolor is slate. The color of the beak is horn, shading to yellow at tip, and the shanks and toes are leaden blue and yellow.

Buckeye.—The Buckeye is an American product resulting from the infusion of blood from the Barred Plymouth Rock, Buff Cochin, Dark Cornish, and Black-breasted Red Game. The comb is pea shaped. The standard weights, in pounds, are: cock, 9; hen, 6½; cockerel, 8; pullet, 5½.

The surface color of the Buckeye is mahogany bay, with a slightly darker shade on the wing bows of the males. The flight and main tail feathers of the male may contain black. The undercolor in both sexes is red, except in the back, where there is a bar of slate across each feather below the surface.

Chantecler.—The Chantecler originated in Canada between 1908 and 1920 from crosses between Cornish, White Leghorn, White Wyandotte, White Plymouth Rock and Rhode Island Red. It is pure white in all sections of its plumage. The most noticeable characteristics of the breed are a conformation resembling that of the Cornish, especially in breast development and carriage, the smallness of the cushion-shaped comb and the very small wattles. The standard weights, in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet, 5½.

ASIATIC BREEDS

Not only have Asiatic breeds been prominent for many decades in the country in which they originated but also they have exercised a tremendous influence in the development of several breeds of other countries. Of the three Asiatic breeds recognized as standard, the Brahma, Cochin and Langshan, only the first two ever gained particular prominence in the American poultry industry. With the development of the American breeds, however, the popularity of the Asiatic breeds was not maintained and they are now bred to a limited extent only.

The breeds belonging to the Asiatic class are of distinctive type and have large bodies, feathered shanks and are usually heavy in bone. All have yellow skin, except the Black Langshan, whose skin is a pinkish white. All have red earlobes, lay brown-shelled eggs and are classed as broody.

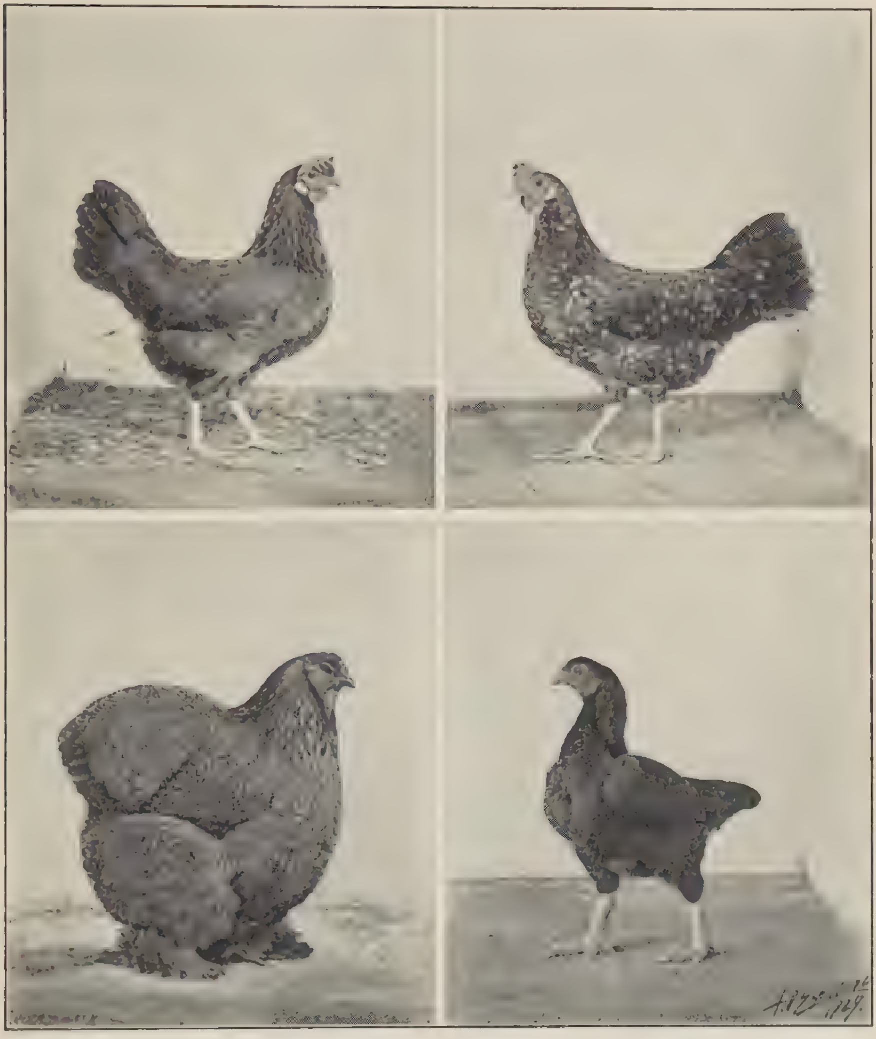
Brahma.—The earliest Brahmas originated in the Brahmapootra district of India, where fowls of the original type, known as "Grey Chittagongs," are still to be found. The Brahma apparently was first imported into America in September, 1846, and into England in 1853.

Brahmas are massive in appearance, well feathered and well proportioned. One characteristic of this breed is its pea comb. The standard weights of the Light Brahma, in pounds, are: cock, 12; hen, 9½; cockerel, 10; pullet, 8; and of the Dark Brahma: cock, 11; hen, 8½; cockerel, 9; pullet, 7.

The Light Brahma has the same color pattern as the Columbian Plymouth Rock and Columbian Wyandotte.

The Dark Brahma has the color pattern of the Silver Penciled Plymouth Rock and the Silver Penciled Wyandotte.

The Buff Brahma has the same color pattern as the Columbian Plymouth Rock except that golden buff or buff replaces white and in the Buff Brahma the shank feathers are buff and the feathers on the outer toe of each foot are buff and black, the black being laced with buff.



S. C. Light Brown Leghorn. S. C. Ancona.
Partridge Cochin. Dark Cornish.

FIG. 8.

Cochin.—The Cochin originated in the Shanghai district of China and was known as the Shanghai fowl. It was first imported into England in 1845 and a little later into America. The outstanding characteristics of the Cochin are its massive appearance and abundantly feathered shanks. The breast of the Cochin is carried low and, in the female, there is a very prominent development of the cushion at the base of the tail. The feathering is extremely long and profuse so that the Cochin appears much larger than is really the case. All Cochins have single combs. The standard weights, in pounds, are: cock, 11; hen, 8½; cockerel, 9; pullet, 7.

The Buff Cochin has the same even shade of golden buff as in Buff Plymouth Rocks and Wyandottes.

The White Cochin in color is like other white varieties, for a description of which see the White Plymouth Rock.

The Black Cochin is the same in color as the Black Wyandotte.

The Partridge Cochin is a parti-colored variety in which the sexes differ materially in feather markings, which are the same as in the Partridge Plymouth Rock and Partridge Wyandotte.

Langshan.—The Langshan originated in the Langshan district north of the Yangtse Kiang river in China. Langshans were imported into England in 1872 and a little later introduced into America. The principal characteristics of the Langshan as compared with the Brahma and Cochin are that the body is shorter but deeper, there is greater length of leg, the tail feathers are longer, and the tail is carried higher. The Langshan stands up well and is well proportioned, which makes it a very graceful bird. The comb is single. The standard weights, in pounds, are: cock, 9½; hen, 7½; cockerel, 8; pullet, 6½.

The Black Langshan has the same color qualifications as the Black Wyandotte except that the beak is dark brown, the shanks and toes are bluish black, and the bottoms of the feet are pinkish white.

The White Langshan is the same in color as the White Plymouth Rock except that the beak is light slate blue shading to pinkish white, and the shanks and toes are slaty blue, with pink between the scales.

ENGLISH BREEDS

The breeds of English origin described in the American Standard of Perfection are for the most part utility breeds noted for their excellent fleshing properties. With the exception of the Cornish, all the breeds have white skin and red ear lobes, and, except the Dorking and Red Cap, lay brown-shelled eggs. All are classed as broody.

Orpington.—The Orpingtons are characterized by their size and shape of body, which is long, deep, and well rounded, with a full breast and a broad back. They are rather low set and heavy in bone. They are a little more loosely feathered than breeds of the American class. The Orpingtons make good table birds and good laying strains have been developed when bred with that object in view. The comb is single. The standard weights, in pounds, are: cock, 10; hen, 8; cockerel, 8½; pullet, 7.

The Black Orpington was produced about 1886 from matings involving the Black Minorca, clean-legged Black Langshans, and black colored specimens with Plymouth Rock blood. For a description of the color plumage see the Black Wyandotte. The shanks and toes are black, and the bottoms of the feet are white.

The Buff Orpington was evolved from Bluff Cochins, Dark Dorkings, and Golden-Spangled Hamburgs. The plumage color is the same as in other buff breeds, such as the Buff Plymouth Rock. The shanks and toes are white.

The White Orpington in all probability originated as a "sport" from the Black variety. The color is the same as in the White Plymouth Rock except that the shanks and toes are white.

The Blue Orpington, originated quite recently, has the same general color as the Blue Plymouth Rock except that the shanks and toes are leaden blue.

Cornish.—The Cornish, originally known as the Cornish Indian Game, appears to have been developed in England about the middle of the last century and was produced from crossings involving the Aseel, Malay, and English Game breeds. It was imported into America in 1887 and gained popularity partly because of its excellent fleshing properties and its yellow skin.

The Cornish is noted for its close feathering and compact, heavily meated body, which has a distinctive shape. The breast of the Cornish is very deep and broad, giving the shoulders great width. All Cornish birds have pea combs. The standard weights, in pounds, of the dark and white varieties, are: cock, 10; hen, 7½; cockerel, 8; pullet, 6; and of the white-laced red variety they are: cock, 8; hen, 6; cockerel, 7; pullet, 5.

The Dark Cornish male has greenish-black hackle and wing bows; the primaries are black except for a narrow edging of bay on the outer edge; the secondaries have the upper webs black and the lower webs black and bay; the back should be lustrous greenish black and dark red intermixed. The tail, lower part of the body, and fluff are black, and the breast is greenish black. In the female the neck is a lustrous black, each feather having a bay shaft; the wing bows are bay. The primaries are almost entirely black; the secondaries have the upper webs black; and the lower webs are black except that there is a broad margin of bay penciling. The back is bay color. The main tail feathers are black except the upper two, which are penciled with bay. The lower part of the body, fluff, and breast are bay with the feathers for the most part penciled. The undercolor of both sexes is dark slate. The beak, shanks, and toes are yellow.

The White Cornish was developed in America and is pure white in plumage color, and the beak, shanks, and toes are yellow.

The White-laced Red Cornish was also developed in America quite recently. The plumage color is quite interesting. It has, in both sexes, bright, rich-red neck feathers, in the male laced with silvery white and in the female with white. In both sexes the back, lower part of body, fluff, and breast are rich red in appearance, each feather regularly laced with a narrow lacing of white. In the male the tail is white; in the female the tail is red, except that the end of each feather is laced with white. The undercolor of all sections in both sexes is white.

Sussex.—The Sussex and the Dorking, described next, are two breeds developed in England about 200 years ago primarily as table birds. In the early history of these two breeds the Sussex were developed from birds with four toes while the Dorkings were developed from birds of the same origin but with five toes.

The Sussex has a long body, broad at the shoulders and with good depth from front to rear. The breast is well developed, and the bird has excellent fleshing qualities. Fowls of this breed have single combs and horn-colored beaks, shanks, and toes. The standard weights, in pounds, are: cock, 9; hen, 7; cockerel, 7½; pullet, 6.

The Speckled Sussex is reddish bay in color, each feather tipped with white. In the male the neck is a lustrous, reddish bay, each feather having a black stripe extending lengthwise. The wing bows also are reddish bay; the primaries are black and white; the secondaries have the outer webs bay edged with white, and the inner webs are black edged with white. The back and saddle are reddish bay; the main tail feathers are black and white; the lower part of body, fluff, and breast are all reddish bay in color, each feather tipped with white. The female is for the most part reddish bay throughout except that the primaries and secondaries are the same as in the male. The undercolor of all sections in both sexes is slate shading to salmon.

The Red Sussex is a deep, rich red in both sexes. The only exceptions to the red color are found principally in the primaries, where the lower webs are black with a narrow edging of red, in the secondaries where the upper webs are black, and the tail, which is black. The undercolor of all sections in both sexes is red with a slight bar of slate.

The Light Sussex was first admitted to the Standard of Perfection in 1929. The color of the plumage is quite similar to the Columbian Plymouth Rock and Columbian Wyandotte.

Dorking.—The Dorkings, like the Sussex, are characterized by long, broad, deep, and low-set bodies. The White Dorking has a rose comb, whereas the other two varieties have single combs. All Dorkings have five toes. The standard weights, in pounds, of the White Dorking are:

cock, 7½; hen, 6; cockerel, 6½; pullet, 5; of the Silver-gray and Colored Dorkings, they are: cock, 9; hen, 7; cockerel, 8; pullet, 6.

The White Dorking is white throughout and should be free from any foreign color, as in other white-colored breeds. The beak, shanks and toes are white.

The Silver-gray Dorking is a particolored bird in which the sexes differ in feather markings.

The male has a white hackle, and the plumage on the front of the neck is black. The wing bows are silvery white; the primaries have the upper webs black and the lower webs white; the secondaries are the same as the primaries except that in the secondaries there is a black spot in each feather. The back and saddle are silvery white, the tail is black and the sickles and coverts are greenish black; the lower part of the body and the fluff are also black.

In the female the neck is silvery gray, each feather having a black stripe extending down its center. The wing bows are silvery white; the primaries have the upper webs dark slate and the lower webs gray; The secondaries are the same as the primaries. The back is grayish white and the tail is black. The undercolor of all sections in both sexes is slate. The beak is white streaked with horn, and the shanks and toes are white.

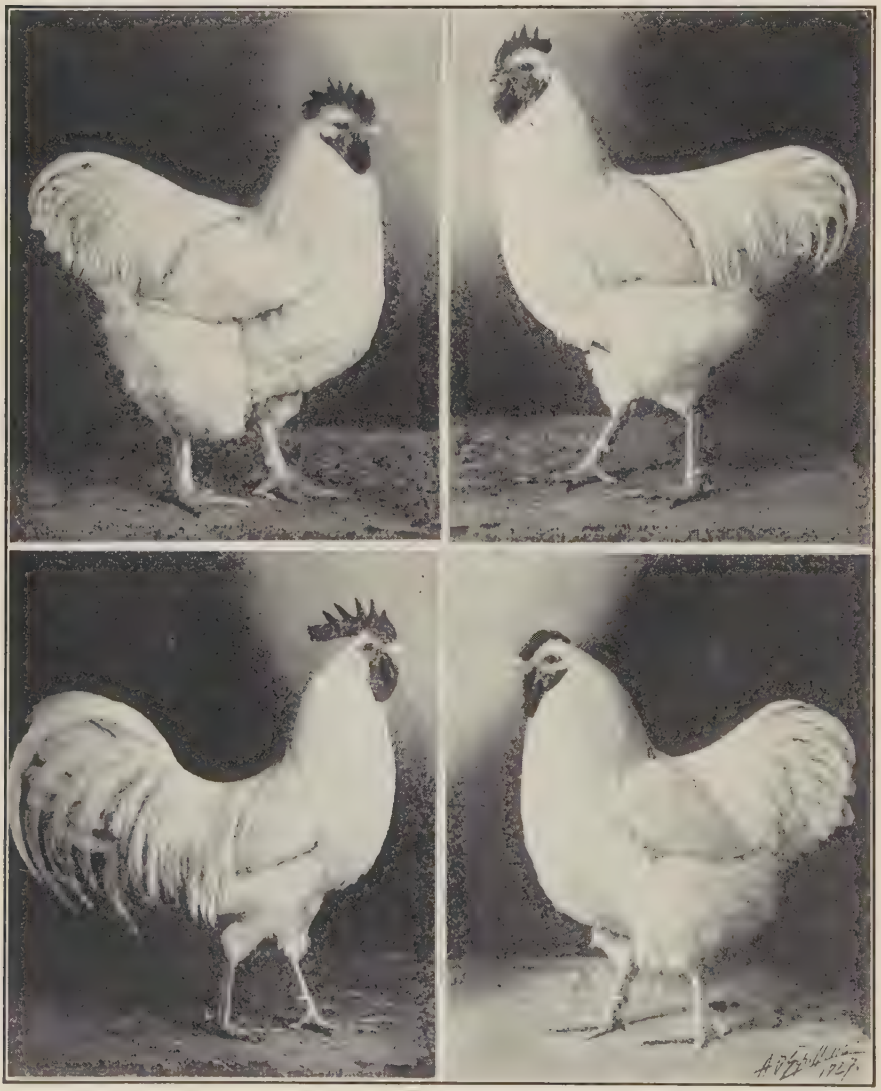
The Colored Dorking is also parti-colored, with sex differences in feather markings.

The male has a light-straw-colored hackle; the wing bows are a light-straw color; the primaries are black or dark slate; the secondaries have the upper webs black and the lower webs white. The saddle feathers are also light-straw color with a black stripe down the middle of each feather. The breast, lower part of body, fluff, and tail are black.

In the female the neck is black with gray edging on the front of each feather; the wing bows are black; the primaries are slaty brown; the secondaries have the upper webs black and the lower webs black with a mixture of dark red. The back of the female is lustrous black; the tail is dark brown; the lower part of the body is black slightly mixed with gray, and the fluff is dull black edged with gray. The undercolor of all sections in both male and female is slate. The beak is dark horn, and the shanks and toes are white.

Red Cap.—The Red Cap is supposed to have been developed from Old English Games and Golden Spangled Hamburgs. The name "Red Cap" is derived from the large rose-comb. It is a bird of medium size with a fairly long body and a rather prominent breast. A large, rose comb is characteristic of the breed. The standard weights, in pounds, are: cock, 7½; hen, 6; cockerel, 6; pullet, 5.

Australorp.—The Australorp is a breed admitted to the Standard of Perfection in 1929. As the name suggests it was developed in Australia from the Black Orpington. It is more upstanding and less massive in appearance than the Black Orpington and has been developed as an egg producer. The back is rather long, with a gradual sweep to the tail and the body is of good depth but the feathering fits more closely to the body than in the Orpington. The comb is single, the beak is black and the shanks and toes are black or leaden black with the bottoms of the



White Orpington.
S. C. White Leghorn.

White Plymouth Rock.
White Wyandotte.

Fig. 9.

feet and toes pinkish white. The plumage color is lustrous greenish black in all sections and the undercolor is dull black. The standard weights in pounds, are: cock, 8½; hen, 6½; cockerel, 7½; pullet, 5½.

MEDITERRANEAN BREEDS

The breeds of Italian origin are smaller than the Asiatic and other classes and in America the Leghorns especially have been bred for egg production rather than for the production of table poultry, except as broilers. The breeds of Spanish origin are somewhat larger than the Leghorns and Anconas, but have not been bred so extensively for egg production. All of the Mediterranean breeds have non-feathered shanks, white or creamy-white ear-lobes, lay white-shelled eggs, and are nonbroody.

Leghorn.—The Leghorn originated in Italy and was first imported into America about 1835 and from America was imported into England. The breed is noted for the graceful blending of its different sections and its stylish carriage. All of the varieties of Leghorns have yellow beaks, skin, shanks, and toes. The standard weights, in pounds, are: cock, 6; hen, 4½; cockerel, 5; pullet, 4. There are single-comb and rose-comb varieties.

The single comb in the male should be of medium size and should stand erect, with five regular, deeply serrated points, the back of the comb extending straight out from the back of the head. In the female the front of the first point should stand erect, but the remainder of the comb should droop to one side. The comb in both sexes should be free from wrinkles, "thumb marks," or folds.

In the rose-comb variety the comb of the male should be of medium size and square in front, well filled and free from hollows, the spike well developed and extending straight back from the head. In the female the comb is small and neat and in shape is like that of the male.

The Single-comb White Leghorn is white throughout and should be free from any brassiness or creaminess, as in other white varieties.

The Rose-comb White Leghorn is identical with the Single-Comb White Leghorn, except for the rose comb.

The Single-comb Light-Brown Leghorn was first imported into America about 1835. It is parti-colored, the female being more sombre-colored than the male. The latter has a hackle of orange color, the lower feathers of which are striped down the middle with black. The breast is black, the wing bows are bright red, the back is reddish brown and the saddle is light orange or lemon; the feathers of the back and saddle should be free from shafting. The dull-black primaries and secondaries have the lower webs edged with brown. The feathers over the lower part of the body are slate tinged with brown. The tail is black.

In the female the neck feathers are golden yellow with a black stripe extending down the center of each feather. The breast is a rich salmon color, and should be free from penciling, stippling, or shafting. The sides of the breast shade gradually to the color of the wings. The primaries are a slaty brown with the outer webs showing a narrow edging of brown. The secondaries are brown, with the outer webs finely stippled with lighter brown. The back, body, tail coverts, wing bows, and coverts in surface color are of light brown, finely stippled with darker brown. The shade of color over the back, wing bows, and coverts should be even and the feathers free from shafting. The fluff and thighs are slate, tinged with brown. The undercolor in both sexes is slate.

The Single-comb Dark-Brown Leghorn male has a dark-red head, a rich-red hackle and saddle, and the feathers are striped with a greenish-black stripe extending through the middle of each feather. The back is of the same shade as the hackle, but is without striping. The wing bows are rich red, the fronts and coverts greenish black, which show as a distinct wing bar when the wing is folded. The primaries are black, the lower webs edged with brown. The secondaries are black, the lower webs showing edges of brown. The tail, body, breast, fluff, and thighs are black. The undercolor throughout is slate.

The female is of a darker shade than the female of the light-brown variety. The neck feathers should be well striped with black. The breast is a dark reddish salmon stippled with brown. The wings and back should be black, stippled with a darker brown. There should be no shafting, but the plumage should show a greenish sheen free from purple. The stippling is much coarser than in the light-brown female. The undercolor should be slate, running quite dark down to the skin.

The Rose-comb Brown Leghorn was produced about 1880 from crosses between the Red Cap and the Golden Spangled and Golden Penciled Hamburgs. In the color pattern the male is the counterpart of the male of the single-comb, dark-brown variety, and the female in color pattern is the counterpart of the single-comb, light-brown variety. At many of the leading exhibitions, however, the Rose-comb Brown Leghorns are divided into two classes, as in the case of the single-comb variety, light brown and dark brown. In such cases the Rose-comb Brown Leghorn male and female are color counterparts of the Single-comb Dark-Brown Leghorn male and female, respectively. The same thing applies to the color of the Rose-comb Light-Brown Leghorn male and female when compared with the Single-comb Light-Brown Leghorn male and female, respectively.

The Single-comb Buff Leghorn is of the same golden-buff color as found in the Buff Plymouth Rock and other buff varieties.

The Rose-comb Buff Leghorn is the counterpart in color of the single-comb buff variety.

The Single-comb Black Leghorn should be black in all sections, showing a lustrous sheen free from purple barring. The undercolor throughout is dull black.

The Silver Leghorn is of relatively recent origin in which the sexes differ materially in feather markings.

The male has a silvery white surface color; the head is silvery white. and the hackle is white, each feather having a median stripe of black, The wing fronts and shoulders are black, the bows are silvery white, the coverts black, forming a distinct bar across the wing. The primaries are black, except for the silvery white outer edges of the lower feathers. The secondaries are also black; the back, saddle, and lower tail coverts are silvery white. The cape, main tail feathers, sickles, upper tail coverts, breast, body, thighs, and fluff are black.

In the female the head and neck are silvery gray, each feather of the latter showing a narrow black stripe. The wing bows and coverts are silvery white, finely stippled with ashy gray, giving these sections a general gray cast. In the primary and secondary feathers the upper webs are gray and the lower webs slaty gray. The front of the neck is a light salmon, and the breast is salmon, fading gradually to the color of the wings at the side. The back, body, and thighs are the same color as the wing bows and coverts. The tail is black, except that the upper two feathers are light gray and the tail coverts are gray. The fluff is a light, ashy gray. In both sexes the undercolor is gray throughout.

The Red Leghorn is a newly-developed variety of Leghorns, having been admitted to the Standard of Perfection in 1929. The color of the surface plumage is an even shade of rich brilliant red and the under-color is red.

The Black-tailed Red Leghorn is also another newly-developed variety of Leghorns admitted to the Standard of Perfection in 1929. The plumage color is practically identical with that of the Rhode Island Red.

The Columbian Leghorn was first admitted to the Standard of Perfection in 1929. The plumage color is similar to that of the Columbian Plymouth Rock and Columbian Wyandotte.

Ancona.—The Ancona originated in the vicinity of Port Ancona in Italy. It was imported into England about the middle of the last century and from England it was later imported into America. It is of the same general type as the Leghorn. The standard weights, in pounds are: cock, 6; hen, 4½; cockerel, 5; pullet, 4.

The Single-comb Ancona and the *Rose-comb Ancona* are the two varieties of this breed, and they are identical in every respect except in the shape of the comb. The single comb is identical in shape with the Leghorn single comb of each sex, and the rose comb in the Ancona female is identical in shape with the Leghorn female rose comb; but in the Ancona male it is slightly smaller than in the Leghorn male.

The Ancona has a plumage color of lustrous black with certain of the feathers tipped with a V-shaped white tip. The proportion of feathers carrying such a white tip varies from one in two to one in five in different sections. The black surface color of the male has a greenish sheen, which is absent in the female. The main tail feathers and sickles of the male and the main tail feathers of the female are each tipped with white. The primary and secondary wing feathers also carry white tips. The undercolor is dark slate throughout. The beak is yellow with the upper mandible shaded with black and the shanks and toes are yellow or yellow mottled with black.

Minorca.—The Minorca either descended directly from the old Spanish Castillian breed or had the same common ancestor, but the more improved Minorcas came from the Balearic Islands off the east coast of Spain. It is noted for its length of body, large comb, and long wattles, and is the largest of the Mediterranean breeds. The long back has a noticeable slope downward from the shoulders to the base of the tail. The tail is carried rather low and is well spread. The breast is prominent and well rounded. The skin of all varieties of the Minorcas is white.

In the single-comb varieties the comb is unusually large. In the male it is erect and has six evenly and deeply serrated points. The blade of the comb has a tendency to follow the neck. In the female also the comb is large, six-pointed, and the front of the comb folds to one side and the remainder droops to the other side of the head.

In the rose-comb varieties the comb of the male is fairly large, square in front, and terminates in a well-defined spike which has a tendency to follow the neck. The rose comb of the female is practically the same in shape as that of the male but is smaller.

The standard weights, in pounds, of the Single-comb Black Minorcas, are: cock, 9; hen, 7½; cockerel, 7½; pullet, 6½. Of the other varieties of Minorcas the weights are: cock, 8; hen, 6½; cockerel, 6½; pullet, 5½.

The Single-comb Black Minorca is black with lustrous, greenish sheen over the surface, which should be free from purple barring. The undercolor is dull black. The beak is black, and the shanks and toes are black or dark slate.

The Rose-comb Black Minorca is identical with the Single-comb Black Minorca in color, but is 1 pound lighter in standard weight.

The Single-comb White Minorca should be white throughout, free from any foreign color. The beak, shanks, and toes are pinkish white.

The Rose-comb White Minorca is the counterpart of the Single-comb White Minorca, except for the comb.

The Single-comb Buff Minorca should be an even, rich, golden buff throughout, as in the case of all buff varieties. The beak is light horn, and the shanks and toes are white or pinkish white.

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White-faced Black Spanish.—*The White-faced Black Spanish* has a very large, pendulous, white face which should be smooth and free from wrinkles. In type the Spanish is very much the same as the Minorca, although it has not quite so long a body and has a somewhat higher carriage of tail. The skin is white. The comb is single and rather large, although not so large as in the single-comb Minorca. It has five regular, deeply serrated points, and the blade extends nearly straight back from the head, having little, if any, tendency to follow the neck. The comb of the female is erect in front and droops to one side. The standard weights, in pounds, are: cock, 8; hen, 6½; cockerel, 6½; pullet, 5½. The plumage color should be black throughout with a lustrous, greenish sheen. The undercolor is dark slate throughout. The beak is black and the shanks and toes are dark leaden blue or black.

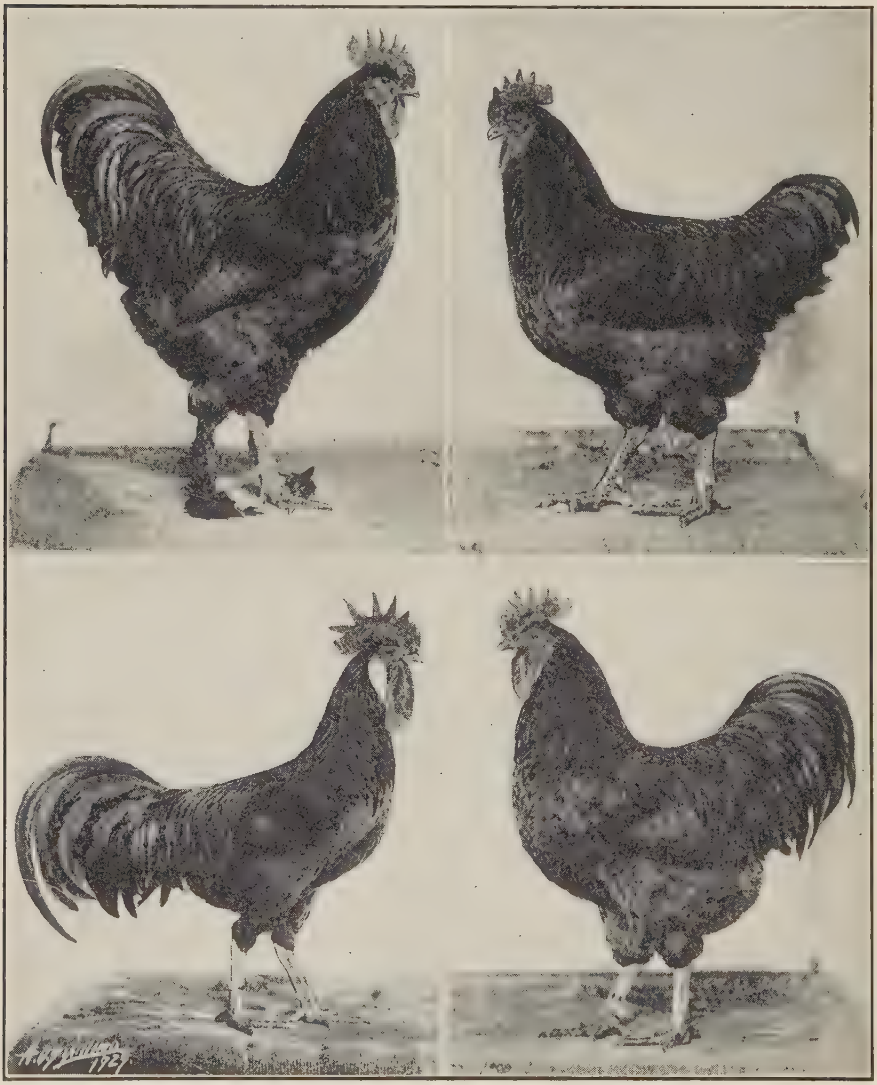
Blue Andalusian.—The Blue Andalusian is of Spanish origin, and is of interest mainly because of its interesting color, which is identical with that of the Blue Plymouth Rock, except that the skin is white, the beak horn-colored, and the shanks and toes leaden blue. The comb is single, that of the male somewhat larger than the comb of the Leghorn, and the blade has a slight tendency to follow the neck. The comb of the female is practically identical with that of the Leghorn female. The standard weights, in pounds, are: cock, 7; hen, 5½; cockerel, 6; pullet, 4½.

CONTINENTAL EUROPEAN BREEDS

A number of breeds of Continental European origin are recognized as standard breeds in the American Standard of Perfection. Very few of them, however, have gained great popularity nor have they become of considerable economic significance and because of these reasons they will be mentioned only briefly. For a more complete discription of the Continental European breeds and varieties the reader is advised to consult the "Standard of Perfection," published by the American Poultry Association (1930), Robinson (1924 and 1925) and Jull (1926a and 1926b). Also, for further information concerning breeds not included in the Standard of Perfection, the following should be consulted: Brown (1929).

The Houdan is a French breed and, like the Dorking, is five-toed. The Houdan gained considerable prominence in France because of its laying and meat-producing qualities. In America, however, it does not hold a very prominent place in the industry. It has a well-developed crest, a beard and a V-shaped comb. There are two varieties, the *Mottled* and the *White*. The standard weights, in pounds, are: cock, 7½; hen, 6½; cockerel, 6½; pullet, 5½.

The Faverolles originated in France from crosses involving the Houdan, Light Brahma, and possibly other breeds. In France it has proved to be a good table bird but has not gained prominence elsewhere. It has a beard, muffs, and feathered shanks. The *Salmon* is the only standard variety recognized in America, although in France there are also the *Light* and the *Black*. The standard weights, in pounds, are: cock, 8; hen, 6½; cockerel, 7; pullet, 5½.



Black Langshan. Jersey Black Giant.
S. C. Black Minorca. Australorp.

Fig. 10.

The Crevecoeur is primarily a Normandy and Picardy breed, descended from the Black Polish. In America the *Black* is the only variety recognized as a standard breed, while France recognizes two others, *White* and *Buff*. The standard weights, in pounds, are: cock, 8; hen, 7; cockerel, 7; pullet, 6.

The La Fleche is another breed of French origin and, like the Crevecoeur, is not very popular in the United States. The general type is somewhat like the Crevecoeur; the plumage color is also solid black. On the other hand, the La Fleche has no crest or beard but has a V-shaped comb which is larger than that of either the Houdan or the Crevecoeur. The standard weights in pounds, are: cock, 8½; hen, 7½; cockerel, 7½; and pullet, 6½. The La Fleche lays a white-shelled egg.

The Campine breed takes its name from the Campine district of Belgium where it was developed several centuries ago. Two varieties are recognized in America, the *Silver* and the *Golden*, the males in both varieties being hen-feathered. The secondary sexual feathers, the hackle, saddle, and lesser tail feathers of the male are of the same shape and approximately the same length as in the female. The standard weights, in pounds, are: cock, 6; hen, 4; cockerel, 5; pullet, 3½.

The Buttercup was imported into America direct from Sicily in 1835. The characteristic feature of the Buttercup breed is the cup-shaped comb. The ear lobe is white. The standard weights, in pounds, are: cock, 6; hen, 4; cockerel, 5; and pullet, 3.

The Polish, according to the best information available, is descended from an old Italian breed and early strains had infusions of other breeds. The outstanding characteristic of the Polish is a well-developed crest surmounting the head and in some varieties there is also a beard. There are no standard weights. Outside of certain sections of Europe the Polish is recognized largely as a fancy fowl. It was imported into America about 1835 and eight varieties are recognized as standard: the *White-crested Black*, the *Bearded* and the *Non-bearded Golden*, the *Bearded* and the *Non-bearded Silver*, the *Bearded* and the *Non-bearded White*, and the *Buff Laced.*

The Hamburg is probably the original rose-comb fowl and its ancestry dates back to the time of the early poultry culture in Holland and Germany. The Hamburg is small in size though there are no standard weights. The comb is rose, the spike of which turns slightly upward. The ear lobe is white. In America six varieties are recognized, the *White*, *Black*, *Golden Spangled*, *Silver Spangled*, *Golden Penciled*, and *Silver Penciled.*

The Malay is a black-red breed which apparently originated in southeastern Asia. The standard weights, in pounds, are: cock, 9; hen, 7; cockerel, 7; pullet, 5.

The Sumatra, a black breed, originated in the islands of the Asiatic Archipelago, including Sumatra. It has a very long, drooping tail and a V-shaped comb. There are no standard weights.

GAME BREED

The Game breed includes a number of varieties, but as a group it has certain definite characteristics. The birds are very striking in appearance, with solidly developed bodies with close-fitting plumage. They stand upright and have great width of the shoulders, with sloping backs and drooping tails. This general appearance is highly prized in the breed and is referred to in the Standard of Perfection as the "station" of the bird. A high-stationed bird is desired. The comb is single, although if dubbed (cut off) it should have a neat and smooth appearance; the comb and wattles of the cock bird should be dubbed. Games lay brown-shelled eggs and are classed as a broody breed.

The varieties of the Game class include the *Black-breasted Red, Brown Red, Golden Duckwing, Silver Duckwing, Birchen, Red Pyle, White,* and *Black.*

MISCELLANEOUS BREEDS

Three miscellaneous breeds recognized as standard in America include the **Frizzle,** with its peculiar development of the feathers which show a tendency to curve outwards at their ends, the **Silkie,** with its blue skin and silky appearing feather formation, and the **Sultan,** with its V-shaped comb, a crest, muffs, beard, and vulture hocks.

Of the many other miscellaneous breeds in the world today, only two will be mentioned, because of their peculiar characteristics. The **Yokohama,** of Japanese origin, is interesting from the fact that some of the tail and saddle feathers are developed to extreme length, sometimes as long as 20 feet. The **Araucana,** of South American origin, is of interest because it has a peculiar growth of feathers on each side of the neck, is frequently rumpless, and lays a light blue tinted egg.

BANTAM BREEDS

Bantams are kept by many to whom the type appeals and who take pleasure in working out the breeding problem that it presents. The development of various color patterns is also an incentive in bantam breeding. Also, many young boys and girls may readily keep a pen of bantams, which in turn frequently leads to an interest in larger fowls.

The breeds of bantams include minatures of the varieties of Games, mentioned previously, and a number of ornamental breeds, including the *Golden* and the *Silver Sebright,* the *White* and the *Black Rose-comb,* the *Light* and the *Dark Brahma,* the *Buff,* the *Black,* the *White* and the *Partridge Cochin,* the *Black,* the *Gray,* the *White* and the *Black-tailed Japanese,* the *Booted White,* and *Mille Fleur Booted Bantam.*

CHAPTER V

THE STRUCTURE OF THE CHICKEN

In the preceding chapter the various breeds and varieties of chickens have been described largely from the standpoint of their external characters, but students of poultry husbandry should have some knowledge of the internal structure of the chicken to gain a proper understanding of fundamental problems involved in the production of eggs, meat and feathers, with their various pattern developments.

The general conception is that the chicken as a whole and its integral parts have resulted through growth but it should be realized that growth alone cannot be responsible for the processes of development whereby the chick is produced from the egg. Something else is necessary to bring about the result and this second process is one of molding and changing of shape, so that out of the single egg cell the complicated form of the chick is produced. The many processes which constitute development, therefore, may be included under two main headings, growth and differentiation.

Significance of Differentiation.—Growth gives rise to increase in size; differentiation gives rise to change in shape, due really to the fact that growth takes place more rapidly in some directions than in others. As a result of both processes, therefore, a chicken comes to have differentiated parts of its organism capable of performing specialized tasks; the eye sees, the gizzard grinds, the glands secrete, the digestive apparatus digests and excretes, the skeleton supports, and the limbs effect locomotion. These various functions are performed by the different organs as a result of specialization of the actual substance of the organism. Nervous tissue differs from glandular, and skeletal from muscular. But the differentiation of the tissues is nothing but the differentiation of the cells of which they are made up and such a differentiation is called *histological differentiation* in contrast with the process of molding and increasing the complexity of the shape of the whole organism which is called *morphological differentiation.*

Adaptation of Parts.—Coincident with differentiation there is adaptation, as implied in the reference made previously concerning the ability of different organs to perform specialized tasks. There are structural adaptations, as seen, for instance, in the well-adapted eye, and in the adaptations of a chicken's skeleton for bipedal progression. The heart is a masterpiece of fitness, and the functional correlations of the heart and lungs are as delicate as they are effective. The adaptive regulatory role of the secretions of the endocrine glands is now known to be of considerable significance in avian physiology. In some cases the reproductive organs of the female seem particularly well adapted to maintain egg production at a high level and for a long time. Thus it is seen that a laying hen is not simply a bundle of characters thrown together indiscriminately but is a harmonious unity possessing an internal equilibrium and a proper adjustment to the external conditions of life, so that the organism persists and works smoothly.

Fast-living Creatures.—The statement that birds are feathered bipeds is sufficient to set them apart from all other animals. But birds are also warm-blooded and the development of the young takes place, for the most part, outside the body of the female. Another interesting thing that should be kept in mind is that birds are "fast-living creatures" as compared with most other animals.

Thomson (1923) points out that birds have a temperature of from 2 to 14° F. higher than that of mammals, while Card (1921) has shown that the normal temperature of White Leghorn chicks the first day after hatching is 106° F. in the morning and 102° F. in the evening. During the first five days after hatching the morning temperature tends to decrease and the evening temperature tends to rise. Simpson (1912) made observations on the body temperatures of five different breeds of chickens and found the average temperature to be 108.4° F. Fronda (1921) observed the average temperature of different breeds of chickens to be 106.7° F. Kaupp (1922) made observations on body temperatures of different breeds and reported an annual mean noon temperature of 107.5° F., but he pointed out that during warm weather the temperature was higher than during cool weather. Evans (1923) says that the temperature of the fowl is 107° F.

Thomson discusses in an interesting way why birds are creatures of intense metabolism. "Continual oxidation or combustion of carbohydrate material is needed to keep the muscles we shall not say 'contracting' but 'able to continue contracting.' The bird's breathing is very rapid. The heart beats very quickly. The blood is astonishingly rich in red blood-corpuscles. The bird is selective in its diet, rarely eating much that is unprofitable, and it makes the most of its food, for the digestion is singularly perfect, as may be seen in the relatively small amount of fæcal matter. In general the bird is a high-geared engine." Thomson speaks of birds in general and he might have added that as compared with the larger domestic animals birds have a larger body surface in relation to bulk, a coating of feathers has to be maintained instead of hair, and in the case of heavy egg production, which is of particular interest in this discussion, it might be further added that there is an additional heavy drain upon the bird's system.

The Skin.—The skin of the bird, of which the comb and wattles are outgrowths, has no glands except a preen gland at the base of the tail and even that is absent in many birds, such as the ostrich and the fantail pigeon. The preen gland is supposed to supply a lubricant to the feathers, especially in such aquatic birds as ducks and geese, but its importance in this respect has been questioned by Paris (1921), who has shown that the obstruction of the canals of the preen gland or its removal apparently makes no difference.

Feathers.—Feathers cover almost the entire surface of the bird's body; they do not spring uniformly from the whole surface of the body but from certain defined areas called "feather tracts." Normally there are ten feather tracts, but Greenwood (1927) has observed that in the breed called the "Transylvania Naked-neck," in which the feathers of the neck are absent, some of the feather tracts are largely reduced if not entirely absent, especially the head and lateral neck tracts.

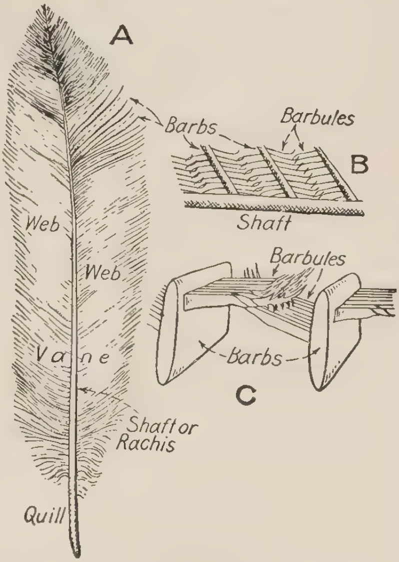


Fig. 11.—The structure of a feather. (*After Evans.*)[1]

In the wings and tail the feathers are in a certain definite order; in the wings the most important feathers are the primaries and the secondaries. The names of the feathers covering the various parts of the chicken are given in the illustration in Fig. 6; the structure of a typical feather is shown in Fig. 11; the arrangement of the feathers in the wing of a chicken is shown in Fig. 12.

It should be noted, of course, that in the great majority of the breeds of chickens the males have feathers over certain parts of the body that are longer and more pointed than feathers springing from the same parts of the body in females. The neck feathers, those over the rear of the back and the tail feathers in males are called "secondary sexual feathers."

There are certain breeds, such as Campines and Hamburgs, in which the males are feathered the same as the females, except that some of the tail feathers may be slightly longer than in females. Such males are called "hen-feathered" males.

The Silkie breed of chickens gets its name from the fact that the barbules of the feathers are hookless, giving the feathers over the entire body a silky appearance. The presence of the silky feathering condition in various races has been discussed by Tegetmeier (1873), Davenport (1906), Bateson and Punnett (1908), Taubert (1910) and Jones (1921).

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[1] Evans, Ernest, "The Biology of the Fowl." By permission of John Dixon, Ltd., publishers.

Coloration.—The coloration of birds is an extremely interesting subject, especially to those who breed chickens with definitely established color patterns and feather markings. Coloration may be produced by pigments, by physical structure, or by a combination of these. Thomson (1923) says that most of the pigments of birds fall into four groups—lipochromes or fatty pigments, melanins, haemoglobin and others. Lipochrome pigments include zoonerythrin (animal red) and zooxanthin, which gives the beaks and feet of many birds their bright yellow color. The melanins produce most of the dark colors of birds. The haemoglobin of the blood is a protein pigment containing iron. Concerning structural colors in feathers, Bancroft (1923) says that the "blacks, reds, oranges, yellows, and browns are pigment colors, but that the ordi-

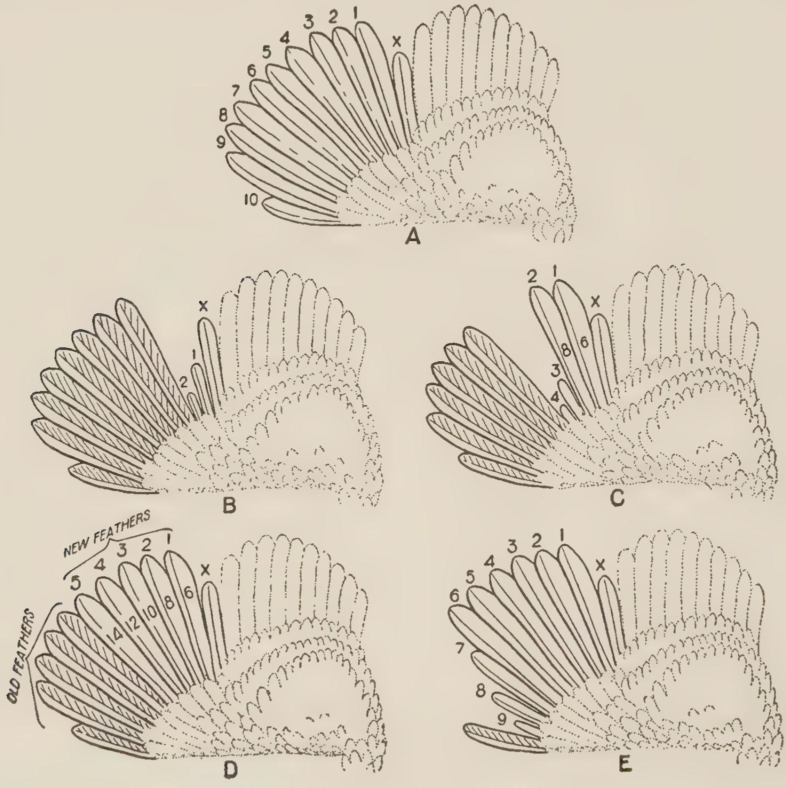

Fig. 12.—*A*, a normal wing showing the primary feathers, 1 to 10. They are separated from the secondary feathers (in dotted outline) by a short axial feather, *X*. *B*, the beginning of a wing molt. 1 and 2 are new feathers growing in. *C*, an 8-week molt. 3 and 4 are not counted until fully grown. *D*, an instance (abnormal) in which five feathers only were molted. *E*, a wing completing a normal molt. (*Kansas Agr. Exp. Sta.*)

nary blues and greens are not blue and green by transmitted light, and that the so-called metallic or iridescent colours, such as those of the peacock, are structural colours." Strong (1905) gives an interesting account of the causes of blue and green in feathers. The subject can not be pursued further at this time, though it would be very interesting to discuss the pigmentary relationships among the barred, laced, penciled and other feathers, illustrated in Figs. 7, 8, 9 and 10.

Skin Color.—The color of the skin of most of the breeds of chickens is either yellow or white, but there is one outstanding exception in the Silky breed with its characteristic purplish blue skin, due to pigmentation. It might be added here that the bones of the Silky are also pigmented.

Shank Color.—Shank colors are of interest inasmuch as in the preceding chapter various breeds have been described as having yellow shanks, others have been described as having white, others as having black and still others as having other shades. The nature of shank color has been briefly summarized by Punnett (1923):[1]

> The shank colours of fowls have been studied in most detail by Barrows (1914), who found that the various colours are due to combinations of three distinct and independent types of pigmentation, *viz.:*
>
> *a.* Black pigment in the epidermis. The scales themselves contain pigment, and the shank is dark whatever may be the underlying condition in the dermis. Probably, however, the darkest type of shank is that in which a pigmented epidermis overlies a dermis which also contains pigment.
>
> *b.* Black pigment in the dermis. When this is present in the deeper layer of the skin beneath the epidermis, and at the same time epidermal pigment is absent, the shank appears of a slaty blue colour. When the more superficial epidermal pigment is highly developed, it is often difficult to determine whether dermal pigment is present or absent.
>
> *c.* A yellow (lipochrome) pigment in the epidermis. When black dermal pigment is also present the willow shank results. Yellow is obscured in the shank by the black epidermal pigment when this is also present, but it can generally be made out by examining the under surface of the foot. The white shank is due to the absence of all three types of pigment.

Eggshell Color.—The color in the shell of many eggs seems to be due to one or more pigments from the blood and bile. Sorby (1875) mentions seven substances as probably producing all colors found in the shell, oocyan, banded oocyan, oorhodeine, yellow ooxanthine, rufous oxanthine, lichnoxanthine, and a substance giving narrow absorption bands in the red.

Yolk Color.—The color of the yolk of eggs has been determined by Palmer (1915) and Palmer and Kempster (1919*a* and *b*) to be due almost entirely to a pigment called "xanthophyll."

The Skeleton.—According to Thomson (1923) "the skeleton of the bird is lightly built, affording a relatively large surface for the insertion of muscles without the corresponding increase of weight that would be involved if the bones were as substantial as those of a reptile or a mammal. The skeleton is built on the hollow girder principle. The long bones have medullary cavities and many bones of many birds contain prolongations of air sacs from the lungs." Jaulmes (1925) has shown that the air sacs are of physiological importance in serving as bronchial circuits. Thomson (1923) further says that the lungs are firmly fastened dorsally to the ribs and they are inexpansible. This arrangement is of interest because in birds the active part of breathing is *breathing out* or expiration in contrast to mammals, in which the active part is *breathing in* or inspiration. Associated with the lungs are the air sacs.

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[1] PUNNETT, R. C., "Heredity in Poultry." By permission of Macmillan & Co., Ltd., London, publishers.

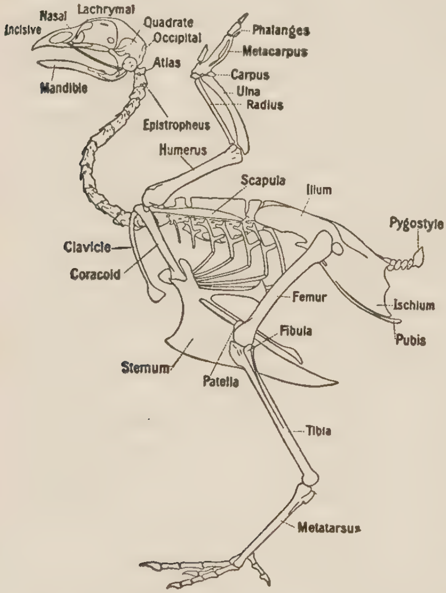

FIG. 13.—The skeleton of a fowl. (*After O. Charnock Bradley.*)[1]

The complete skeleton is shown in Fig. 13, but only a few of the more important bones will be mentioned here. The spinal column or backbone consists of 42 bones, divided, according to Kaupp (1918*a*), into four principal regions, the cervical region forming the neck of the fowl and composed of 14 bones, the dorsal region forming in part the roof of the chest cavity and composed of 7 bones, the lumbo-sacral region forming the roof of the pelvic cavity and composed of 14 bones, and the coccygeal region forming the tail and composed of 7 bones, including the last bone of the tail, the pygostyle, so-called because it is formed like a plough-share. du Toit (1913), however, says that there are 16 bones in the lumbo-sacral or synsacrum region and that the tail has 5 free caudal vertebræ and the pygostyle. It is interesting to note that fowls sometimes appear in which not only the pygostyle and free caudal vertebræ are missing but also the last two vertebræ of the synsacrum. Such fowls are called "rumpless" and their anatomy has been described by Landauer and Dunn (1925).

Other bones of the skeleton of interest to students of poultry husbandry include the humerus, radius and ulna, from which section of the wing spring the secondary feathers of the wing, and the carpometacarpus, from which section of the wing spring the primary feathers of the wing. The sternum or keel bone is characteristic of all normal fowls although

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[1] BRADLEY, O. CHARNOCK, "The Structure of the Fowl." By permission of A. and C. Black, Ltd., publishers.

Dunn (1924*a*) has described a White Leghorn with the keel entirely missing. The different bones of the hind limb are shown in Fig. 13 and it will be observed that the metatarsus is the bone which is covered with scales and is commonly referred to as the "shank" in judging and describing chickens. Cutler (1925) has described chickens in which tibia and fibula of the hind limb are much shortened, so much so that the birds are called "creepers." Apparently the fibula develops more slowly than the tibia, causing the latter to be bent forward and thickened near the "hock."

Most breeds of poultry have four toes but there are a few, such as the Silkie, Dorking and Houdan, which have five toes as the normal number. Danforth (1919) describes a condition in which the toes of the foot are shortened, this condition usually being associated with the presence of feathers on the tarsi.

The development of bone and its repair are discussed by Kaupp (1917).

Other details of the structure of the skeleton will not be discussed here except to refer to some of the more important features taken into consideration in selecting hens for egg production. Figure 13 shows the skeletal structure by which the width, depth and other features of the body of a bird are determined, and particular attention is called to the location of the pubis or pubic bones.

The Alimentary Tract.—The alimentary or digestive tract of the chicken consists of the organs directly concerned in the reception of feed, its passage through the body and the excretion of the unabsorbed portion. The digestive tract includes the alimentary canal and the accessory organs. The alimentary canal extends from the mouth to the anus and includes the mouth, pharynx, oesophagus or gullet, crop, proventriculus or glandular stomach, gizzard, duodenum, small intestine, large intestine, rectum, cloaca and anus. The accessory organs include the beak, tongue, salivary glands, liver, spleen and pancreas.

The mouth parts of chickens consist of the upper and lower mandibles and the tongue, all of which are used principally in the apprehension of feed.

The alimentary tract of birds differs materially from that of mammals. The absence of teeth in birds is compensated for by the development of a horny beak covering the jaws and by the presence of a gizzard. The pharynx is a muscular region at the back of the mouth and serves to grip the food in the process of swallowing. The gullet or oesophagus is an elastic tube, lubricated internally by mucus glands, and it leads to the crop and from the crop again to the glandular stomach or proventriculus, as shown in Fig. 14. The crop serves as a storage pouch, whereby birds are enabled to eat a large meal "between times."

The gizzard is a very important organ serving to grind the food and in some respects takes the place of teeth in other animals. It is oval in shape and has a huge development of musculature on two opposite walls with numerous fibers radiating outward from a central tendinous disc. The entrance from the glandular stomach into the gizzard is not far from the exit from the gizzard into the duodenum or duodenal loop. The internal lining of the gizzard is really a secretion, called "pseudocuticula." When food is present in the gizzard the two muscular walls contract in a grinding motion. According to Lippincott (1927), "the gizzard is a very efficient crusher. Reaumur (1750) stated that iron tubes capable of supporting a weight of 535 lb. have been completely flattened out by passing through the gizzard of a turkey. Spallanzani (1784) showed that a hen's gizzard, empty of grit, could bend and wear down sharp pieces of steel, without being injured." The function of grit in the gizzard is discussed in the chapter on Digestion and Metabolism.

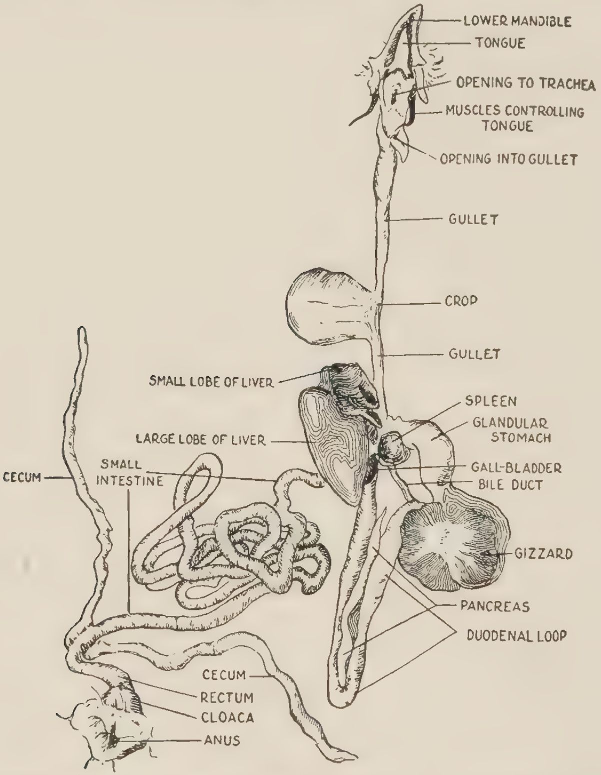
LOWER MANDIBLE
TONGUE
OPENING TO TRACHEA
MUSCLES CONTROLLING TONGUE
OPENING INTO GULLET
GULLET
CROP
GULLET
SMALL LOBE OF LIVER
SPLEEN
GLANDULAR STOMACH
LARGE LOBE OF LIVER
GALL-BLADDER
BILE DUCT
CECUM
SMALL INTESTINE
GIZZARD
PANCREAS
DUODENAL LOOP
CECUM
RECTUM
CLOACA
ANUS

Fig. 14.—The alimentary or digestive tract of a fowl. (*After William A. Lippincott.*)[1]

The first section of the intestine is called the "duodenum," into which open the two ducts of the pancreas, which lies between the folds of the duodenum, as shown in Fig. 14.

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[1] Lippincott, Wm. A., "Poultry Production." By permission of Lea and Febiger, publishers.

The liver communicates with the duodenum by means of two or three ducts, one of the ducts being connected with the gall-bladder, which stores the bile secreted by the liver. The spleen lies in a triangle formed by the proventriculus, gizzard and liver and is a small, reddish-brown gland.

The intestine proper is comprised of the small and the large intestine. The small intestine lies in folds in the body, the mode of looping in different birds, according to Newton (1893), being definite and constant so that in related birds there are similar patterns of looping. At the junction of the small and the large intestine or rectum there is a valve, called "ileocaecal," which prevents a return of food contents. Arising from the same place are two blind diverticula, the caeca, each usually from 4 to 6 in. in length. The large intestine or rectum is relatively short and leads to the cloaca, which also receives the ureters from the kidneys and the reproductive ducts. Krüger (1926) states that in fully matured fowls the length of the intestine varies from about 170 to 260 cm. (66.81 to 102.18 in.).

Just posterior to the cloaca is the anus, the terminal portion of the alimentary tract.

The Urinary System.—The kidneys, of which there are two, lie imbedded underneath the hip girdle and are composed of three lobes. They receive their blood mainly from the renal arteries and return it to the renal veins, which join the great posterior vein, the inferior vena cava, leading back to the heart. The kidneys are very dark colored and serve to strain off from the blood certain deleterious substances in the form of urine. From each kidney the urine is carried to the cloaca in a small tube called the "ureter," shown in Figs. 15 and 16. It will be seen, therefore, that in birds the urine is mixed with the fecal matter in the cloaca before both are extruded, whereas in mammals the urine and feces are extruded from the body separately.

The Reproductive Organs.—The reproductive organs in both male and female are called "gonads." In the male the reproductive organs consist of a pair of testes, or testicles, from each of which there is a tube, called *vas deferens*, leading to the cloaca, as shown in Fig. 15. At the base of the *vas deferens* there is an enlargement called the "seminal vesicle" for holding the sperm. The testes are situated at the anterior ends of the kidneys and are small, yellow-colored bodies, though Bittner (1925) has observed that they are frequently pigmented by melanotic pigment. There is a tendency for the right testes to be larger than the left and Pearl (1918) has reported the same relationship in healthy doves and pigeons. The reproductive cells of the male, called "spermatozoa," are secreted in the testes and pass through the *vas deferens* to the seminal vesicle, and at the time of mating are passed through the cloaca.

The male has a rudimentary copulatory organ, which has been described by Dove (1928) and Yamaguch (1928).

The reproductive organs of the female, shown in Fig. 16, consist of the ovary and the oviduct on the left side of the body. In the embryo chick a right ovary and a right oviduct also develop but they degenerate as the development of the chick proceeds, so that at hatching time only rudiments remain. Atwood and Snyder (1922–1923), however, describe a White Leghorn which laid eggs of two distinct shapes, each having a characteristically different shape index, suggesting the presence of two functional ovaries and oviducts. Kaupp (1922) shows a photograph of the gonads of a hen illustrating two functional ovaries and oviducts. These must be taken as rare exceptions.

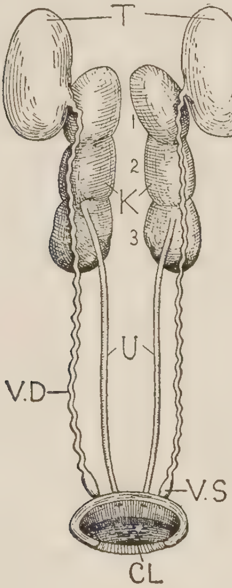

Fig. 15.

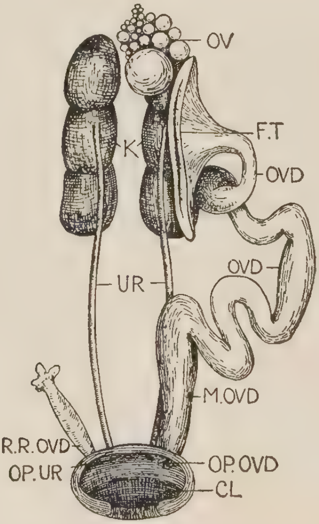

Fig. 16.

Fig. 15.—The reproductive organs and urinary system of the male fowl. *T*, testes; *K*, 1, 2, and 3, lobes of the kidneys; *V.D.*, vas deferens; *U*, ureters; *V.S.*, seminal vesicle for storing spermatozoa; *CL*, cloaca. (*After Thomson.*)[1]

Fig. 16.—The reproductive organs and urinary system of the female fowl. *OV*, ovary; *K*, kidneys; *FT.*, funnel of the oviduct; *OVD*, oviduct; *M.OVD*, uterus of the oviduct; *UR*, ureters; *R.R.OVD*, rudimentary right oviduct; *OP.UR*, opening of the right ureter; *OP.OVD*, opening of the oviduct; *CL*, cloaca. (*After Thomson.*)[1]

The left ovary lies at the anterior end of the kidney attached to the dorsal wall of the body cavity by a fold of peritoneum. When the ovary is in an inactive condition, as in the case of a young pullet, it appears as a small whitish mass of irregular contour having a finely granular structure, whereas when in an active condition the ovary appears as a yellowish cluster of cells, like a bunch of grapes.

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[1] Thomson, J. Arthur, "The Biology of Birds." By permission of The Macmillan Company, publishers.

The oviduct is a much coiled tube filling a large part of the left half of the abdominal cavity and leads from just behind the ovary to the cloaca, as shown in Fig. 16. It is suspended from the dorsal body wall by ligaments, which, according to Curtis (1910), undergo a progressive change in shape and size relations as the oviduct assumes functional activity. Curtis also observed that the alimentary tract forms a pocket in which the ovary lies and that this arrangement tends to direct the ova mechanically toward the mouth of the oviduct, the ostium tubæ abdominale or funnel, opening into the body cavity near the ovary.

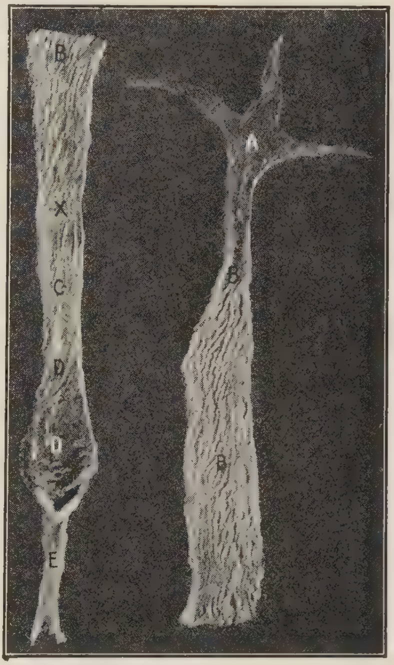


FIG. 17.—Photograph of an oviduct slit lengthwise and opened and cut into two pieces to save space in illustrating. *A*, mouth or funnel; *B*, albumen-secreting portion; *X*, line of demarcation between the albumen-secreting and the isthmus portions; *C*, isthmus; *D*, uterus; *E*, vagina. (*After Pearl and Curtis.*)

A complete description of the oviduct, illustrated in Fig. 17, is given by Surface (1912), who showed that it is divided into five different parts, beginning with the mouth, or funnel, mentioned above. The second region is called the "albumen secreting region," for it is in this region that the dense albumen of the egg is secreted. The third region is called the "isthmus," the fourth the "uterus," which, as Thomson (1923) observes, is badly named, and the fifth region is called the "vagina," which opens into the cloaca.

The Regulatory System.—There are a number of internal organs in birds which produce secretions which frequently exercise a marked influence on different parts of the bird's body or in the development of various characters. These organs of internal secretion are all comparatively small and they all are ductless and are known as endocrinal glands. The fluid substances they produce are carried away by the blood and distributed throughout the body.

There are several groups of endocrinal glands, including the thyroids, the parathyroids, the pituitary gland, and the adrenals or suprarenal glands. It might also be said that there is a thymus gland located in the throat of the chicken, but it degenerates after the first year. In each bird there is a pair of thyroids lying at the base of the neck and associated with them are the parathyroids. The thyroid glands have been described by Scheskin (1925) as being egg shaped with a yellow appendix.

The pituitary gland is a small body which hangs down from the base of the brain, while the adrenal organs appear as small bodies on the front part of each kidney. The secretions produced by the endocrinal glands are called "hormones" and their function will be discussed later.

Other Systems.—The nervous, muscular and circulating systems are not discussed because a discussion of them would hardly be germane to the problem raised in this book. In fact, the brief discussion concerning the structure of the chicken in this chapter has been given with a view toward a clearer understanding of fundamental problems involved in poultry husbandry. For a more detailed discussion of the anatomy of the chicken, reference is made to Shufeldt (1888), Beddard (1898), Bradley (1915), du Toit (1913), Kaupp (1918*a*), Thomson (1923), Evans (1923) and Coues (1927). For information on performing surgical operations in fowls, attention is directed to an article by Nonidez (1924*a*).

CHAPTER VI

THE FORMATION OF THE EGG

There is usually an enormous number of ova in the ovary of a laying hen. Pearl (1912) observed from 914 to 3,605 ova in various stages of development in different hens, but the number present in any hen appears to bear no relationship to her laying ability, although Pearl and Schoppe (1921) observed a general relationship between the average number of ova present and egg production in different orders of birds.

Each ovum begins as a microscopic point in the ovary and is similar to the reproductive cells of mammals. It is contained in a very thin envelope called the "follicle," which is attached to the ovary by a slender stalk or pedicel. The ovum consists of a finely granular protoplasm enclosed in a pellicle called the "vitelline membrane." Embedded in the protoplasm is the nucleus.

Yolk Accumulation.—As the female chicken approaches laying condition, the immature ova begin to accumulate yolk, which is carried to the ovary by the blood and the lymph in the form of dissolved proteins and fatty acids. In each ovum the yolk granules are secreted in concentric layers, beginning first with a layer of light yolk, which forms a flask-shaped structure beneath the germinal disc, and then a layer of dark yolk, and this alternation of layers of physically different kinds of yolk continues until the ovum is ready to be discharged from the ovary. Riddle (1911) determined that the light yolk is accumulated during the night, the time of low blood pressure in the laying hen, while the dark yolk is accumulated during the day, the time of high blood pressure, and that there is produced during every 24 hr. an average thickness of 2 mm. of light and dark yolk layers combined. The arrangement of alternate zones can be seen in a hard-boiled egg cut through the middle with a sharp knife.

The layers of dark yolk are much wider than those of the light yolk and both parts serve as food material for the developing embryo rather than being transformed into the body of the chick. One apparent exception to the preceding statement is in the case of a thin layer of light yolk immediately surrounding the germinal disc, which, according to Coues (1927), is transformed into the body of the chick.

The difference between the light yolk and the dark yolk, according to Thomson (1923), is determined by the nature of the yolk granules and by the fact that the light yolk contains more water than the dark yolk.

The increase in the size of each ovum takes place quite rapidly, although all of the ova do not accumulate yolk granules at the same time but follow each other in successive order until each is sufficiently developed to be liberated from the ovary. The rate of growth of each ovum is not regular, for Riddle (1916*a*) observed that when the ovum of the chicken reaches a diameter of 6 mm. the rate of growth suddenly increases about twenty-five fold until a size of approximately 40 mm. in diameter is attained, this being the approximate size of the yolk of a normal egg. During the growth of the ovum the follicle enlarges and, when the ovum is ready to be liberated from the ovary, the follicle bursts along a streak called the "stigma." Subsequently, the ruptured follicle degenerates. The ovum as it escapes from the follicle is still contained in its vitelline membrane.

Vitelline Membrane.—The vitelline membrane is of composite structure, as shown by Lecaillon (1910). The vitelline membrane proper is a delicate non-cellular layer immediately surrounding the ovum, outside of which there is a layer of degenerating epithelium, and outside of that again is a layer of connective tissue, the last two layers having been contributed by the follicle.

Ovulation.—The ovum just before being liberated from the follicle of the ovary is embraced by the mouth or funnel of the oviduct, which normally lies pressed against the ovary although Pearl and Curtis (1914) have shown that the pressure from the funnel is not necessary for ovulation, a term used with reference to the passage of the ovum from the ovary. Moreover, Lillie (1919) has observed that the funnel of the oviduct is able to grasp ova that have dropped into the body cavity. If ova that are dropped into the body cavity are not taken up by the oviduct, they may be absorbed or they may cause serious and fatal disturbances.

Albumen Secretion.—Immediately after the funnel of the oviduct has grasped the ovum it is passed down the four remaining sections of the oviduct by peristaltic action. Pearl and Curtis (1914) give a detailed account of the formation of the various parts of the white or albumen of the egg and the shell membranes and shell, all of which serve to protect the germinal disc in the yolk. The ovum requires approximately three hours to pass through the albumen-secreting portion of the oviduct, during which time about 40 to 50 per cent by weight of the albumen of the egg is secreted, including the chalazæ and the dense albumen, as shown in Fig. 18. The stimulus giving rise to the secretion of albumen is partly mechanical as shown by Tarchanoff (1884), Weidenfeld (1905) and Curtis (1914*a*), but there is also a stimulus of a physiological character, as shown by Tarchanoff (1884).

The two chalazæ are dense portions of albumen twisted in opposite directions and are attached on opposite sides of the yolk to a dense layer of albumen surrounding the yolk. The chalazæ serve the important function of mooring and steadying the yolk in the albumen, and Coues (1927) observes that they are attached to the inner shell membrane. No other workers have confirmed this view, however, and, from numerous observations, it seems doubtful if the chalazæ are actually attached to the inner shell membrane.

Approximately one hour is required by the ovum and the albumen already secreted to pass through the isthmus of the oviduct, where the shell membranes are deposited. The shell membranes lie very close together except where the air cell appears in the egg, usually at the blunt end. The outer shell membrane is thicker than the inner, both being composed of organic fibers.

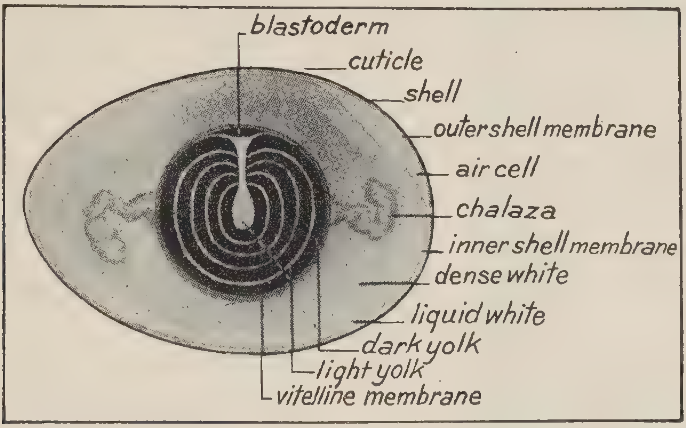


FIG. 18.—Parts of a fertile egg. The blastoderm is popularly called the germ spot. (*After Lippincott.*)[1]

Formation of Shell Membranes and Shell.—Then the ovum with its surrounding materials passes into the so-called "uterus" of the oviduct where the balance of the albumen is secreted and, since the latter is required to pass through the shell membranes by osmosis, it is quite liquid in character. About 5 to 7 hr. are required for this process and before it is completed a portion of the shell has been deposited on the outer shell membrane, as shown in Fig. 19. Approximately from 12 to 16 hr. are required for the completion of shell formation and the passage of the egg through the cloaca. According to Pearl and Surface (1909*a*), the stimulus which excites the shell-secreting glands is mechanical rather than chemical in nature. The shells of the eggs of several breeds are stained with pigment before being laid. The egg may be laid either with the blunt end or the pointed end foremost.

[1] LIPPINCOTT, WM. A., "Poultry Production." By permission of Lea and Febiger, publishers.

The shell is composed of two layers and a cuticle. The inner or mammillary layer consists of very minute calcarious particles so arranged as to provide air spaces for the passage of gases. The second layer is a spongy layer consisting of matted calcarious salts, which are also arranged to provide porosity. The cuticle, on the outside of the egg, is apparently structureless but is porous.

The porosity of the shell and the shell membranes is necessary to allow the embryo chick to respire by exhaling carbon dioxide and by inhaling oxygen. The porous character of the shell also allows water to evaporate from the egg.

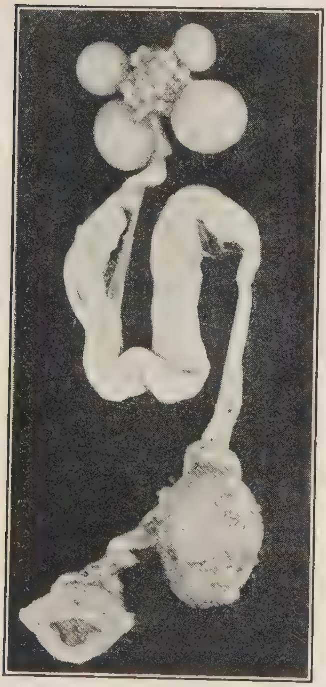


Fig. 19.—Showing ovary containing ovary with yolks in different stages of development and the oviduct containing a fully-formed egg in the uterus. (*Photograph by Roy E. Jones.*)

Herrasti (1916) found that the average breaking pressure for brownshell eggs was 154.8 lb. and for white-shell eggs 112.4 lb. Taylor and Martin (1928) found that hens receiving an insufficient supply of vitamin D produce eggs with thinner shells than hens receiving an abundance of vitamin D. They also found that Barred Plymouth Rocks and White Leghorns laid eggs differing significantly in shell percentage.

Egg Shape.—Most eggs are oval with one end larger and more blunt than the other. Factors that may operate in producing the characteristic oval shape have been studied only slightly. Cushny (1902) observed that the muscular layer of the uterus of the oviduct was thicker than other regions so that the uterus apparently exercised the greatest influence in producing shape. Szielasko (1905) suggested that the uterus gave the egg its definite form while Thompson (1908) felt that the oval shape was due largely to the nature of the pressure exerted by the oviduct, the pressure being greatest behind the middle of the egg due to the nature and direction of the peristaltic action. Pearl (1909*a*), however, observed that the shape of the egg is determined by the muscular activity of the walls of the uterus.

Egg Size.—The total weight of the egg obviously is determined by the collective weights of its component parts. The determination of the weights of the different parts based on the fresh weight has been determined by Curtis (1911) as the most accurate method. In the annual production records of a representative group of Barred Plymouth Rocks, Jull (1924*a*) found that the average percentage of total weight represented by albumen was 58.43, yolk 30.99 and shell 10.58.

But the percentage weights of the different parts of the egg and the weight of the egg itself varies during the annual production record of any individual. The annual production of any bird is composed of several cycles, which are periods of production alternating with periods of either decreased production or entire cessation of production; each cycle is composed of litters, a litter constituting a period of fairly continuous production without a marked break; and each litter is composed of clutches, a clutch representing continuous production for successive days (Curtis, 1914*a* and Goodale, 1918*c*). Féré (1898*a*) claimed that the eggs at either end of the litter are smaller than the intermediate ones but Warner and Kirkpatrick (1916) found that neither small nor large eggs are necessarily laid at the beginning nor end of a hen's laying period but are more likely to be laid during the time of heavy egg production. On the other hand, Atwood (1914 and 1923*a*), Curtis (1914*a*), Hadley (1919), Benjamin (1920), Jull (1924*b* and 1925) and Lippincott, Parker and Schaumburg (1925) have all shown that egg weight tends to increase as production continues during the first year, and the first three investigators also found that after the first year of production egg weight was fairly stable. Atwood (1926) found that the average weight of the eggs during the second year of production was approximately 9 per cent greater than the average weight during the first year of production, and it was also shown that the ration fed the laying hens apparently affected egg weight. Atwood (1917*b*) and Jull (1924*b*) have shown that the second egg of a two-egg clutch is usually smaller than the first egg.

Concerning variations in the percentage weights of the different parts of the egg, Curtis (1914*a*) has shown that yolk, albumen, and shell weight all show seasonal fluctuations, the shell weight varying more than that of the other two, and albumen weight varying more than yolk weight. While Atwood (1917*b*) has shown that the heavier the egg the smaller is the total percentage of egg that is yolk, and Jull (1924*a*) observed that the component parts of the egg contribute in different degrees at different times of the year toward the total egg weight, Pearl (1910*a*) says that "there probably exists a definite relation between the amount of albumen secreted by the oviduct in any given case and the amount of yolk present in the oviduct." Again, Pearl and Curtis (1916) in a study of the component parts of dwarf eggs make a similar observation. On the other hand, Jull (1924*a*) concluded that there is independent variation in respect to the amount of yolk deposited and albumen secreted, and that the quantitative character of the relation between the amount of yolk and the amount of albumen in normal eggs produced throughout the year involves underlying physiological processes.

Abnormal Eggs.—Occasionally an abnormally small or an abnormally shaped egg may be produced by a hen, dwarf eggs being by far the most common. The latter have been studied by Pearl and Curtis (1916), who observed that 35 per cent of the dwarf eggs contained no yolks and that in a few of the others the yolk granules were not enclosed in a vitelline membrane. Dwarf eggs differ in respect to size and shape and, frequently, there is also a difference in internal structure. Bonnet (1883) found that the nature of the albumen is generally altered. Only in a few cases did Pearl and Curtis (1916) find that dwarf eggs were produced by hens with abnormal laying organs. Apparently dwarf eggs result from the secretion of albumen, shell membranes and shell as a result of a stimulus having been exerted upon the oviduct, though in many cases no yolk at all or only a small portion of yolk is present.

Double-yolked eggs have been described by Valenciennes (1856), Panum (1860), Ackers (1895), Féré (1898*a*), Parker (1906), Patterson (1911), Glaser (1913,) Curtis (1914*b* and 1915) and Roberts and Card (1929). The laying of eggs with two yolks is of fairly common occurrence and seems to be due to the liberation of two ova from the ovary at approximately the same time, or to the fact that one ovum may have dropped into the body cavity and was picked up by the mouth of the oviduct at approximately the same time that another ovum was liberated from the ovary, or one ovum liberated from the ovary the day previous to the second ovum may have been arrested in its progress through the oviduct until the second one caught up to it.

Eggs with three yolks have been described by Pearl (1910*a*) and their origin is apparently due to the combination of circumstances producing eggs with two yolks.

Other kinds of abnormal eggs are sometimes produced, as mentioned by Landois (1878), who has described three eggs fused together, von Nathusius (1895), Hargitt (1899), Herrick (1899), who describes the case of an egg within an egg, Chidester (1915) and Weimer (1918). Such abnormal eggs are usually the result of a temporary physiological disturbance in the oviduct.

A triple-shelled egg has recently been obtained from a Rhode Island Red at the U. S. Animal Husbandry Experiment Farm at Beltsville, Md. A normal egg, with white and yolk, was contained on the inside. It was surrounded by a small amount of albumen and another shell, and surrounding the second shell was more white and another shell, the outside shell being about 3¼ in. long and 2½ in. broad.

Soft-shelled eggs are usually most prevalent in the spring of the year, when egg production is at its height. Such eggs may have been laid prematurely, before there was time for the secretion of the shell in the uterus, or they may be due to a physiological disturbance in the laying hen due to the fact that calcium for shell formation is not secreted at the same rate as the albumen and inner and outer shell membranes are secreted.

Still other eggs which might be regarded as abnormal, include bloody eggs, those with blood clots, and those with foreign objects such as pieces of the tissue of the oviduct and in very rare cases eggs containing worms. Bloody eggs and those with blood clots are due to a hemorrhage of the oviduct, or in case of blood clots perhaps a hemorrhage in the ovary, from which blood escapes and is enclosed with the albumen in the shell membranes and shell. Occasionally a piece of the oviduct or perhaps a portion of the follicle surrounding the ovum becomes engulfed in the albumen as it is secreted. Finally, authentic cases have been reported of the presence of worms in eggs, due apparently to the escape of the worms from the intestinal tract into the body cavity, later gaining entrance to the oviduct and later being enclosed in the egg.

The Egg a Closed System.—The egg is essentially a reproductive cell and its complex structure serves to ensure that the embryo chick as it develops within the egg is given every possible protection as well as being provided with food. The egg may be regarded as a complete entity and as Needham (1925) so well points out: "Moreover, bacteria which in the adult animal 'line every natural approach' are absent or almost so from the egg. We deal with a closed system."

CHAPTER VII

JUDGING CHICKENS ON THE BASIS OF STANDARD AND PRODUCTION QUALITIES

In a previous chapter descriptions have been given of the ideal bird in each of the standard breeds and varieties recognized by the American Poultry Association and it was pointed out that the majority of the breeds possess egg-laying and meat-producing qualities. Although it is true that every poultry breeder desires birds of the ideal breed type and variety color or other quality called for in the Standard of Perfection, it is obvious that very few birds attain the ideal. Hence, it is natural that poultry breeders judge their fowls from the standpoint of the extent to which they approach the ideal.

STANDARD QUALITIES

Score-card Judging.—For the purpose of judging chickens according to their standard qualities a scale of points has been developed, whereby each bird may be scored and its various sections given a certain number of points. The total number of points given for each section is a measure

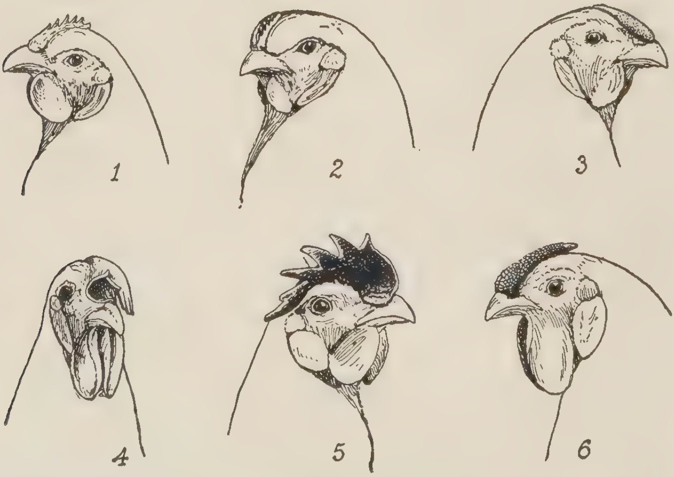


FIG. 20.—Types of combs on females of different breeds. 1, single (Plymouth Rocks and Rhode Island Reds); 2, pea (Brahmas); 3, rose (Wyandottes); 4, single (Minorcas); 5, single (Leghorns); 6, rose (Rhode Island Reds). (*U. S. Dept. Agr.*)

of the relative value of that section compared with other sections. Certain values are given to the weight of the bird as well as to its symmetry and vigor and condition. The theory of score-card judging is to teach students in poultry husbandry and breeders the relative merits of the different sections of the bird as well as to bring out differences that may exist among the birds being judged.

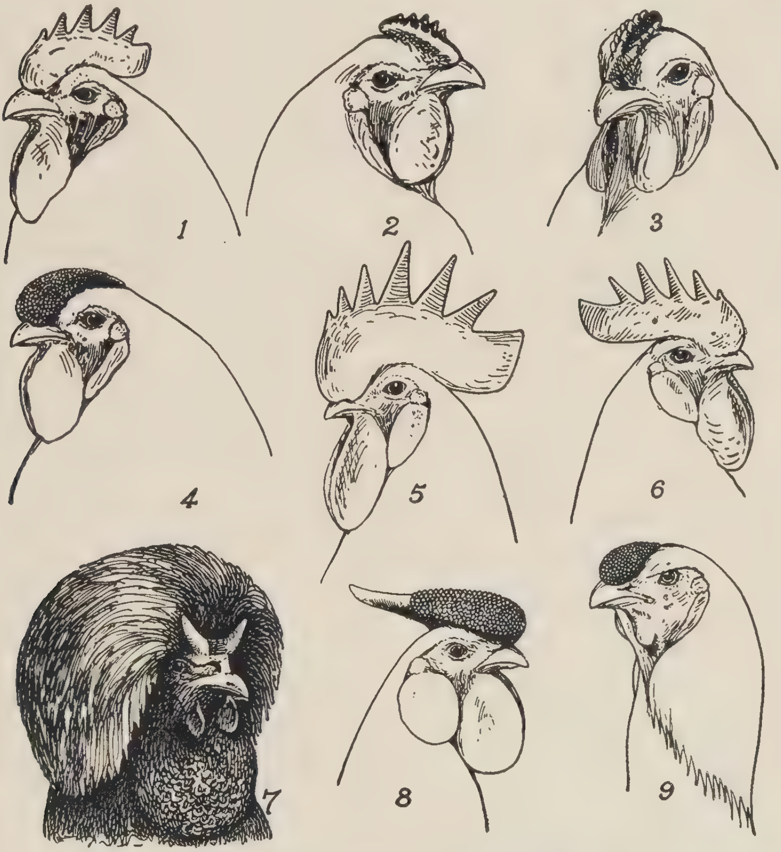


FIG 21.—Ideal types of combs on males. 1, single (Plymouth Rock); 2 and 3 pea (Brahma); 4, rose (Wyandotte); 5, single (Minorca); 6, single (Leghorn); 7, V-shaped (Houdan); 8, rose (Hamburg); 9, strawberry (Malay). (*U. S. Dept. Agr.*)

Judging birds by the score card is of great value in impressing upon the mind of the person doing the scoring the merits and demerits of the different shape and color sections. The different sections of the adult chicken are shown in Fig. 6. The scales of points for chickens of the American and Mediterranean breeds are given in Table 17. The scales of points for other breeds are given in the Standard of Perfection.

TABLE 17.—SCALE OF POINTS USED IN JUDGING AMERICAN AND MEDITERRANEAN BREEDS[1]

	American breeds			Mediterranean breeds		
	Shape	Color	Total	Shape	Color	Total
Weight	. .	. .	4	. .	. .	4
Symmetry	. .	. .	4	. .	. .	4
Vigor and condition	. .	. .	6	. .	. .	6
Comb	. .	. .	6	. .	. .	6
Beak	2	2	4	2	2	4
Head	2	2	4	2	2	4
Eyes	2	2	4	2	2	4
Wattles	2	. .	2	2	. .	2
Earlobes	2	2	4	3	3	6
Neck	3	5	8	3	5	8
Wings	4	6	10	4	6	10
Back	6	6	12	6	6	12
Tail	4	4	8	6	4	10
Body and fluff	5	3	8	3	2	5
Breast	5	5	10	5	5	10
Shanks and toes	3	3	6	3	2	5
Total	. .	. .	100	. .	. .	100

[1] For the scale of points for other breeds consult the American Standard of Perfection.

Comparison Judging.—While the judging of birds by the score-card method is of great value to beginners and students, experienced judges and breeders usually judge chickens in poultry shows by the comparison method. Each bird is handled individually, but the birds are compared among themselves as units rather than being scored section by section. The same situation exists in the judging of horses, cattle, sheep and swine; students in animal husbandry are taught to score each animal individually, but in the live-stock shows judging is done by the comparison method without individually scoring each animal.

DISQUALIFICATIONS AND DEFECTS

In the judging of chickens it becomes obvious that not only are no two chickens alike but also that some of them may have rather serious defects in one or more sections. For instance, a bird may be desirable in every respect except that it has a crooked back or other deformity. A single-comb male bird may be apparently almost a perfect specimen except for a badly lopped comb, illustrated in Fig. 22, or the comb may possess side sprigs, illustrated in Fig. 22. In breeds characterized by having unfeathered shanks there may appear on the shanks feather-like growth or stubs, or bits of down may appear between the toes. The tails of some birds may depart so much from the normal shape that they are either wry tailed or squirrel tailed, as shown in Fig. 23.

Some of the defects mentioned above are transmitted and all of them as well as others described in the Standard of Perfection are regarded as such serious departures from the ideal shape and color standards desired that these defects are called "disqualifications." A bird possessing any one of them is barred from winning a prize in the showroom and should not be used in the breeding pen. Some birds may have certain shape and color defects which do not constitute disqualifications but for which cuts in scoring are provided. These defects are listed in the Standard of Perfection together with the minimum and maximum cuts in points allowed for each defect.

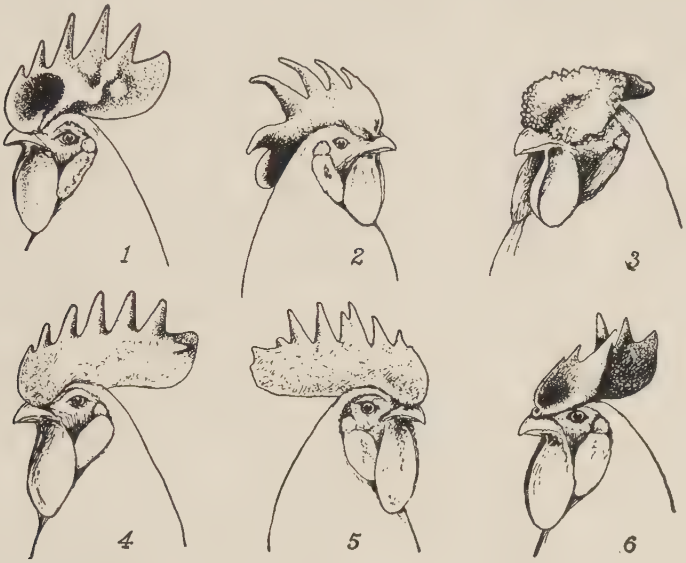


Fig. 22.—Defective types of combs on males. 1, thumb mark; 2, lopped; 3, hollow center; 4 side sprig; 5, uneven serrations; 6, twisted. (*U. S. Dept. Agr.*)

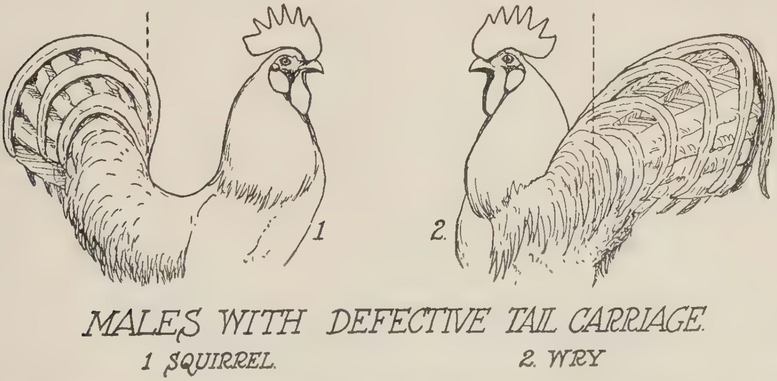

1
2.
MALES WITH DEFECTIVE TAIL CARRIAGE.
1 SQUIRREL.
2. WRY

Fig. 23.—Males possessing these defects should not be used as breeders. (*U. S. Dept. Agr.*)

PRODUCTION QUALITIES

Poultry breeding as an industry lies at the foundation of poultry husbandry and the many diversified standard breeds and varieties of domestic chickens which have been produced from a very small number of originally ancestral forms is striking evidence of the degree to which man has developed and extended his control over the natural processes of reproduction. It is a truism that man's fancies have led to the production of many of the standard breeds and varieties of chickens known to us today, and the satisfaction of having developed something new has constituted one of the best stimuli in man's efforts to understand the laws of inheritance. In a practical world, however, which we find ours to be, there has been a growing demand for the production of chickens that meet man's needs as well as his fancies. The production of eggs and poultry meat becomes of more importance as the human population increases faster than mankind's available food supply. Therefore, more and more is the poultry breeder confronted with the question: How can he best select and breed his chickens for the production of offspring possessing the most desirable qualities?

The selection of birds on the basis of production qualities has always been called "culling," implying that poor or non-layers are "culls" and should be marketed. In actual marketing practice, however, the term "cull" means an inferior product. Thus there has developed a confusion of terms, particularly in the minds of the buyers of live poultry. If instead of using the term "cull" to designate the non-layers the term "market pullets" or "market hens" were used, it would greatly simplify matters. Also, if instead of using the term "culling," flock owners would use the term "selecting," it would still further simplify matters. It is realized, of course, that the term "culling" gained wide popularity because the objective sought was the removal of unprofitable layers. In eliminating the poor layers or non-layers, however, the flock owner was obliged to "select" his best layers in order that they should not be marketed. Also, in selecting his best layers he was at the same time selecting the best birds for subsequent breeding purposes.

Factors in Selecting Layers.—Five different sets of factors are of service in selecting the best layers from the poorest ones. These sets of factors are: (1), temperament in relation to production; (2) head type in relation to egg production; (3), body type and changes in relation to egg production; (4) changes in pigmentation in relation to egg production; (5) the time of molt in relation to egg production.

Temperament in Relation to Production.—There is a difference in temperament between hens, a difference which can be detected at least between a very good and very poor layer. The very good layer is always active in the daytime, whereas the very poor layer is frequently inclined to be sluggish. The very good layer is more nervous and spends more time searching for food, for she is off the roost earlier in the morning and back to roost later at night.

Head Type in Relation to Production.—Since the head of the hen is the headquarters of the central nervous system, it is to be expected that the type of head should serve in some way as an index of producing ability. The head of a good layer is broad but of fine quality as compared with the extremely narrow or very coarse and "beefy" head frequently observed on the poor layer. The eye of the good layer is bright and full whereas in the poor layer it is frequently dull and sunken.

A smooth waxy condition of the comb and wattles is an indication of good productive ability. Their state of development and condition serve as an excellent criterion as to whether or not the hen is laying. If they are fully developed and bright red, the hen is probably laying heavily; if the comb is warm though not particularly full or bright red, the hen is probably just finishing a laying period; if the comb is cold, dried and shrunken, the hen is not laying.

Body Type and Changes in Relation to Production.—The good layer must have good width and depth of body to give her sufficient capacity not only for the formation of eggs but also for a large digestive system for the efficient digestion of large quantities of feed.

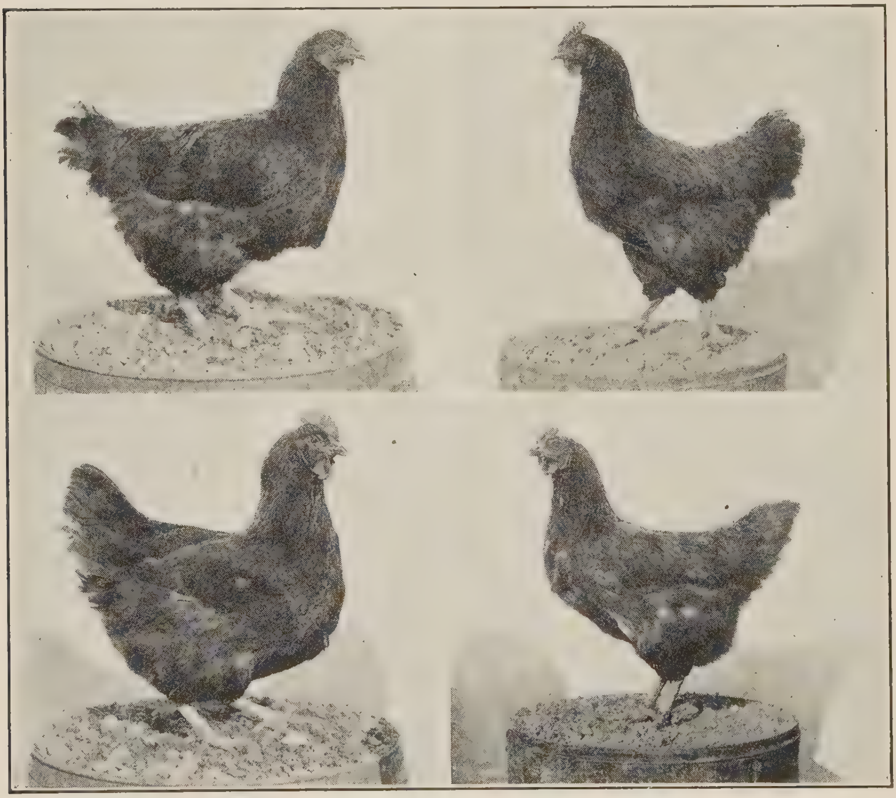
The skin of the good layer is more soft and pliable than that of the poor layer and there is less tendency to accumulate fat in the body because the good layer uses it up instead of storing it.

The pubic bones are more apt to be soft and pliable in the good layer than in the poor one. Their distance apart, as measured by the finger, is an indication as to whether or not the pullet or hen is about to lay or is laying. Also, a moist vent indicates laying whereas a dry vent indicates not laying.

Changes in Pigmentation in Relation to Production.—The yellow pigment in the beak and shanks of breeds that normally have yellow skin color tends to disappear as egg production continues. According to Palmer (1915), the intensity of the pigment is due in part to the presence in some feeds of a carotinoid pigment called "xanthophyl." Yellow corn and green feed contain xanthophyl, but, if rations are fed that do not contain this pigment, the beaks and shanks may be relatively pale, even though the hens may have laid but few eggs. Therefore, the judging of hens for egg production on the basis of changes in pigmentation should always take into account the kind of feed given the hens.

When normally yellow-skinned breeds are given feeds rich in the pigment, the commencement of laying diverts the pigment received in the feed to the yolks, according to Palmer and Kempster (1919*a*). Continuous production tends to deplete the pigment contained in the beak and shanks, first demonstrated by Blakeslee and Warner (1915).

The order in which the pigment disappears from different parts of the bird is from the vent, then from the eye ring, which is formed by the inner edges of the eyelid, then from the earlobes of breeds having normally white earlobes, then from the beak, beginning at the base and extending toward the tip, and finally from the shanks, disappearing first from the front of the shank and later from the rear. Under average conditions a completely bleached beak indicates that the hen has been laying for from 4 to 6 weeks whereas completely bleached shanks indicate that the hen has been laying for from 15 to 20 weeks. When laying ceases, the pigment reappears in the different parts of the body in the same order in which it disappeared.



30 eggs. 231 eggs.
137 eggs. 272 eggs.
Fig. 24.—Rhode Island Red pulletts. (*U. S. Dept. Agr.*)

Blakeslee, Harris, Warner and Kirkpatrick (1917) give the data in Table 18 regarding the mean annual production of groups of White Leghorn hens selected on the basis of vent, beak and shank color. Their results were confirmed by Dougherty (1918) and Sherwood (1922)

TABLE 18.—MEAN ANNUAL PRODUCTION OF GROUPS OF WHITE LEGHORN HENS SELECTED ON THE BASIS OF VENT, BEAK AND SHANK COLOR
(Data of Blakeslee, Harris, Warner and Kirkpatrick, 1917)

Color class	Number of birds and mean annual production					
	Vent		Beak		Shanks	
	Birds	Production	Birds	Production	Birds	Production
Pale	101	189.5	114	184.3	141	178.6
Medium	91	152.2	80	163.3	104	160.5
Yellow	183	136.3	181	131.8	130	123.4
Entire flock	375	154.5	375	154.5	375	154.5

Molting.—The heavy layer is usually a late molter whereas the poor layer may molt as early as July or August. About six weeks are required to renew completely the primaries next to the axial feathers and an additional two weeks to renew each of the remaining primaries. The manner of the molting of the wing feathers is shown in Fig. 12.

Selecting Chart.—Payne (1929) gives the following chart which presents the whole matter in brief form:

JUDGING FOR PRESENT PRODUCTION

Character	Laying Hen	Non-laying Hen
Vent	Large, dilated, oblong, moist	Small, contracted, round, dry
Pubic bones	Flexible, and wide apart	Rigid, close together
Comb	Large, red, full, glossy	Small, pale, scaly
Wattles and lobes	Prominent, soft, smooth	Inconspicuous, rough, and dry

JUDGING PAST PRODUCTION

Character	Long-laying Period	Short-laying Period
Vent	Bluish white	Flesh colored
Eyelids	Thin and edges white	Thick, yellow tinted
Eye	Prominent, keen, sparkling	Listless, sunken
Earlobes	Enamel white	Yellow tinted
Beak	Pearly white	Yellow tinted
Face	Clean cut, sunken	Full, well fleshed, yellowish
Shanks	White, flat, thin, creased	Yellow, round, smooth
Plumage	Worn, soiled, lifeless, close feathered	Signs of molting, loose feathered

JUDGING RATE OF PRODUCTION

Character	High Rate	Low Rate
Keel	Slopes downward	Slopes upward
Pubic bones	Tips thin, point straight out	Tips thick, curved in
Capacity	Four to five fingers	Two fingers
Abdomen	Soft, pliable, dilated	Fatty, hard, contracted
Rump	Broad, width carried back	Narrow, cramped
Lateral processes	Prominent, pointed outward	Hard to find, pointed inward
Skin	Soft, thin, loose, silky	Thick, dry, underlaid with fat

Important Factors.—The whole problem of selecting good and poor layers is discussed in considerable detail by Jackson and Curtis (1923). Knox and Bittenbender (1927) found, among a number of measurements made, that the most significant correlation was the distance between the pubic bones, the size of the abdomen and egg production in August. Hall, Marble and Rice (1928) give detailed instructions regarding selecting for egg production and present a number of colored photographs. Ackerson, Blish and Mussehl (1928) present a series of charts representing the average progress of wing molt in Leghorn hens. Buchanan (1928) shows a number of illustrations of high and low producers and concludes as follows:

> A study of the various cuts in this bulletin indicates definitely that good hens have clean cut heads; slender necks; long backs; long breast bones; and deep, slab-sided, angular bodies, free from excessive fat. Poor hens have fat beefy heads, or slim snaky heads; thick necks; rounded, plump, shallow bodies; and short, narrow backs.
>
> In actual practice, hens will be found all the way between these extremes. It is the job of the poultryman, who undertakes to cull his flock, to be able to recognize these types. It is easy enough to take out the real culls. The job is to be able to determine which way to put those that are on the borderland between culls and mediums; and to decide how many of those that approach the ideal type should be classified as good.

Steup (1929) emphasizes the importance of good head features, pointing out that the most desirable features include flatness of skull from side to side, width of skull carried well forward, good depth of head in relation to its length, and levelness of the top of the skull from front to rear.

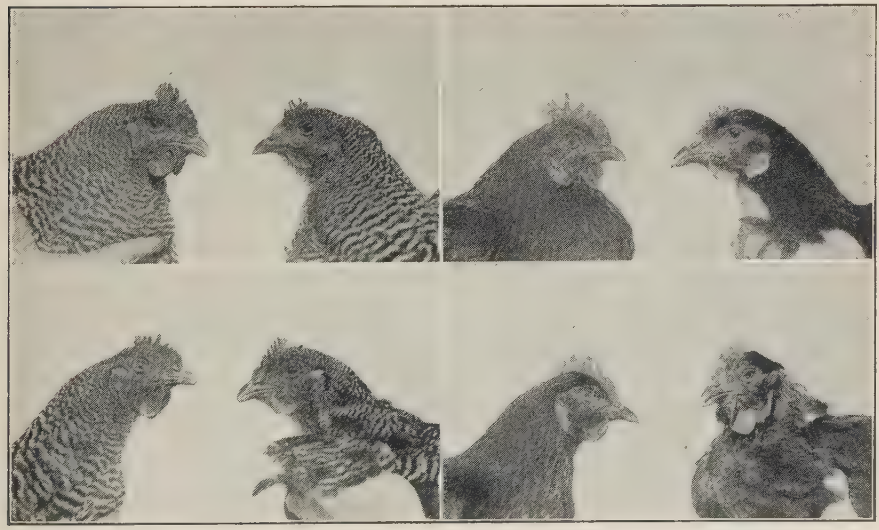
Principles of Selection.—It should be borne in mind that in selecting hens for egg production two sets of characters are taken into consideration, physiological characters and morphological characters. The physiological characters include the pigmentation of beak, earlobes, shanks, vent, molting and probably the distance between the pubic bones. The morphological characters include body measurements relating to form.

Physiological Characters.—The amount of correlation between each of several physiological characters and egg production has been determined by a number of investigators. Sherwood (1922), and Hervey (1923*b*), secured the results shown in Table 19 with 128 and 197 White Leghorn pullets, respectively, the year of production in Sherwood's case being from Oct. 1 to Sept. 30, and in Hervey's case from Nov. 1 to Oct. 31.

The results of the two investigators are quite comparable and in every case the correlation coefficient is significant in comparison with its probable error. In connection with these findings, however, an important fact should not be overlooked. In each case the character studied is a physiological one whose condition at the time of observation is probably determined by antecedent egg production. Concerning the physiology of pigmentation, for instance, Palmer and Kempster (1919*b*) have observed that loss of pigmentation in the beak, shanks, vent and earlobes is caused by the deflection of the normal path of excretion of xanthophyll from those parts to the egg yolk as a result of egg production.

TABLE 19.—CORRELATION BETWEEN ANNUAL EGG PRODUCTION AND SEVERAL PHYSIOLOGICAL CHARACTERS IN WHITE LEGHORN PULLETS
(Sherwood and Hervey)

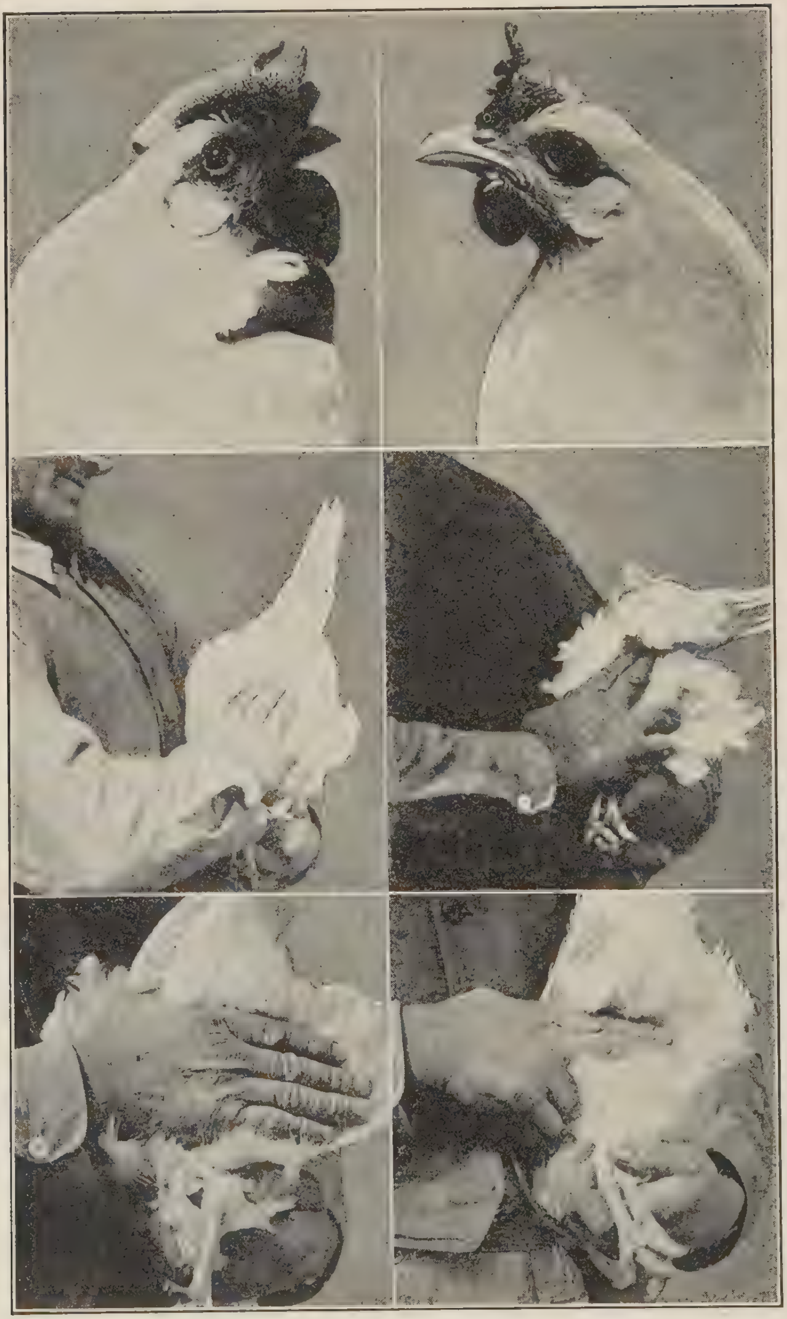
Correlation coefficients between annual egg production and	Sherwood	Hervey
Pigmentation of beak	−0.603 ± 0.038	−0.480 ± 0.037
Pigmentation of shanks	−0.622 ± 0.037	−0.293 ± 0.044
Pigmentation of vent	....	−0.356 ± 0.042
Pigmentation of earlobes	....	−0.271 ± 0.044
Molting	−0.522 ± 0.043	−0.454 ± 0.038
Spread of pubic bones	+0.210 ± 0.057	+0.403 ± 0.040



204 eggs. 69 eggs. 205 eggs. 30 eggs.
288 eggs. 81 eggs. 263 eggs. 155 eggs.

FIG. 25.—Head types and egg production. (*Photograph by U. S. Dept. Agr.*)

Concerning the phenomenon of molting, of particular interest is the physiological relationship between egg production and the time of year that molting occurs as well as the rate of molting. Whether the factors which determine the time of year that molting normally occurs and the



Good head.
Good width between pelvic bones.
Good body capacity.

Poor head.
Poor width between pelvic bones.
Poor body capacity.

FIG. 26.—Three important steps in judging hens for egg production. (*Photograph by Purina Mills.*)

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rate of molting are factors which also bring about cessation of or decreased egg production or whether definite factors controlling egg production bring on the molt apparently have not been established. Which is cause and which is effect no one seems to know.

Concerning the distance apart of the pubic bones, it is apparent that the condition of this character is affected by antecedent production. It seems safe to assume, therefore, that each of the physiological characters under discussion serves primarily as an index of past performance rather than of future breeding worth.

Morphological Characters.—The problem of selecting males and females for breeding purposes would be immensely simplified if morphological characters could be used as a basis for determining breeding worth. The poultry breeder would then know what value to place upon such characters as beetling eyebrows, roach backs, rocker keels, slab-sidedness and wedge shape. Then, if through inheritance studies, it is found that males possessing these characters tend to transmit them to their offspring whether mated to females possessing similar or other characters, and that females possessing these characters tend to transmit them to their offspring whether mated to males possessing similar or other characters, the poultry breeder would be provided with a most ready means of selecting the most desirable birds for future breeding purposes by physical examination alone.

The amount of correlation between annual production and each of a few morphological characters has been determined by two investigators, Asmundson (1921) and Sherwood (1922). The former investigator used 280 White Leghorns, over one-half of which consisted of birds in

TABLE 20.—CORRELATION BETWEEN ANNUAL EGG PRODUCTION AND MORPHOLOGICAL CHARACTERS IN WHITE LEGHORNS

(Asmundson and Sherwood)

Correlation coefficients between annual egg production and	Asmundson	Sherwood
Body capacity	+0.228 ± 0.038	+0.093 ± 0.059
Length of keel	+0.032 ± 0.040	+0.208 ± 0.057
Depth of body 1	+0.368 ± 0.035	+0.174 ± 0.058
Depth of body 2	+0.253 ± 0.037	
Width of hips	+0.356 ± 0.035	
Straightness of keel	+0.164 ± 0.039	
Curvature of keel	±0.116 ± 0.040	

[1] The measurement of depth of body was obtained by Asmundson by determining the distance from the anterodorsal surface of the ilium to the rear of the keel, and by Sherwood by determining the distance from the upper joint of the femur to the rear of the keel.

[2] Asmundsen also determined the distance between the anterodorsal surface of the ilium and the front of the keel and regarded this as a truer index of depth of body than the other measurement.

their first laying year and the balance in their second laying year, and the latter investigator used 128 White Leghorns in their first laying year. The results of their studies are shown in Table 20.

A glance at the results of the two investigators reveals two important features: there is considerable lack of uniformity in the results of one compared with the other investigator and the correlations are all of relatively low value. Apparently no definite conclusions can be drawn concerning the relationship between form and egg production. This does not mean that this original piece of work by these two investigators is of negative value; rather their results point to the necessity of much further work being done and involving a larger number of characters. So far as the results go, however, they do suggest that egg production may be found to be correlated with depth of body, width of hips (back) and possibly other morphological characters.

The problem has been analyzed further, however, by Knox (1924) and by Waters (1927). Knox used 96 White Plymouth Rocks and took measurements once monthly during November, December and January, his findings being shown in Table 21.

TABLE 21.—SUMMARY OF STATISTICAL CORRELATIONS FOR CHARACTERS STUDIED WITH INTENSITY OF EGG PRODUCTION
(Knox, 1924)

Characters	Coefficient of Correlation
Capacity of lay bones	+0.358 ± 0.061
Thickness of pubic bones	+0.026 ± 0.069
Span of pubic bones	+0.147 ± 0.068
Capacity of abdomen	+0.108 ± 0.069
Body capacity	+0.019 ± 0.070
Total capacity	+0.011 ± 0.070

Waters analyzed data secured from 200 Single-comb White Leghorns at the Storrs International Egg Laying Contest, about one-half of the birds being in laying condition at the time the measurements were taken. The measurements were taken during the last three weeks of October, at the close of the contest year, the data being shown in Table 22.

It will be observed that the only significant correlation determined by Knox was that between the capacity of the lay bones and intensity of production. From the findings determined by Waters, he drew the following conclusions:

> Body depth and length of keel, as measured, when used as a possible standard for judging capacity showed no correlation with annual egg production. No correlation was found between weight of bird and annual egg production. There is no correlation between relative size of head and annual egg production. Efforts to predict egg production by measurements of anatomical characters gave only negative results.

TABLE 22.—SUMMARY OF COEFFICIENT OF CORRELATION BETWEEN ANNUAL EGG PRODUCTION AND THE OTHER CHARACTERS STUDIED

(Waters 1927)

Characters Correlated with Annual Egg Production	Coefficient of Correlation
Body weight	−0.021 ± 0.047
Ratio of weight to body depth	−0.016 ± 0.047
Ratio of weight to length of keel bone	−0.035 ± 0.047
Ratio of weight to length of comb	−0.009 ± 0.047
Ratio of weight to length of beak	−0.035 ± 0.047
Ratio of weight to width of cranium	−0.032 ± 0.047
Ratio of weight to depth of head	−0.065 ± 0.047
Body depth	−0.025 ± 0.047
Length of keel bone	−0.069 ± 0.047
Length of comb	−0.024 ± 0.047
Length of beak	−0.029 ± 0.047
Width of cranium	−0.192 ± 0.045
Depth of head	+0.100 ± 0.047

Sherwood and Godbey (1928) used Single-comb White Leghorns at the Texas Agricultural Experiment Station and studied the characters, weight, shank color, handling quality, capacity, molt, length and width of back, depth of body in front, and egg production. They concluded that with the methods of measurement commonly employed it is impossible to develop a score card that can be used for judging birds on the basis of production qualities.

CHAPTER VIII

THE INHERITANCE OF CHARACTERS

That the fertilized egg can carry the total heritage of the complex adult, that it can give rise in the course of 21 days to a fully formed chick, is one of the marvels of nature. From a mere speck on the surface of the yolk of the egg, there develops the embryo and then the fully formed chick and finally the adult with its many bodily characters. Though everyone appreciates the fact that life comes from life, there are too few who realize that the many characters comprising the individual are inherited from generation to generation in a definite manner.

Many Different Kinds of Characters.—Every chicken is composed of a large number of characters, so many, in fact, that it would be impossible to enumerate them all here but enough are mentioned to illustrate their diversity.

All chickens have feathers, but some have all black feathers, others have all white feathers, still others have barred feathers, and still others have feathers of various colors. Feather color is a character and its inheritance has formed the subject of numerous investigations.

The wild fowl, *Gallus Bankiva*, has a single comb, but there are modern breeds and varieties with single, rose, pea and walnut combs. The shape of the comb is a character that is inherited in a definite manner.

The Polish and Sultan breeds have crests, while most breeds have no crests; Brahmas, Cochins and Langshans have feathered shanks, while all of the American breeds have non-feathered shanks; the Dorking and Houdan have five toes, while practically all other breeds have four toes; the Leghorns are noted for their non-broodiness, while certain other breeds or strains may be noted for the broodiness they manifest; some birds are noted for their egg-laying ability, while others are noted for their non-laying activity.

These and other characters that might be mentioned, such as white, yellow, or black skin, and size, shape and color of egg, are all inherited fron generation to generation, most of them in a definite manner, as has been demonstrated in practical breeding operations.

THE INHERITANCE OF A PAIR OF CHARACTERS

The manner in which black and white are inherited in a cross between Rose-comb Black and Rose-comb White Bantams will serve to illustrate the mechanism of heredity involved in the inheritance of most pairs of characters. In this case black is one character and white the other and when a Black Rose-comb Bantam is mated to a White Rose-comb Bantam the chicks produced are all black; it makes no difference which sex is black or which is white. Now when these black chicks are mated among themselves they produce chicks in the proportion of three blacks to one white. The mating of the parents gives rise to the first hybrid generation, which in turn, when mated among themselves, give rise to the second hybrid generation. The parental generation is represented by the symbol P, the first hybrid generation by F_1 and the second hybrid generation by F_2.

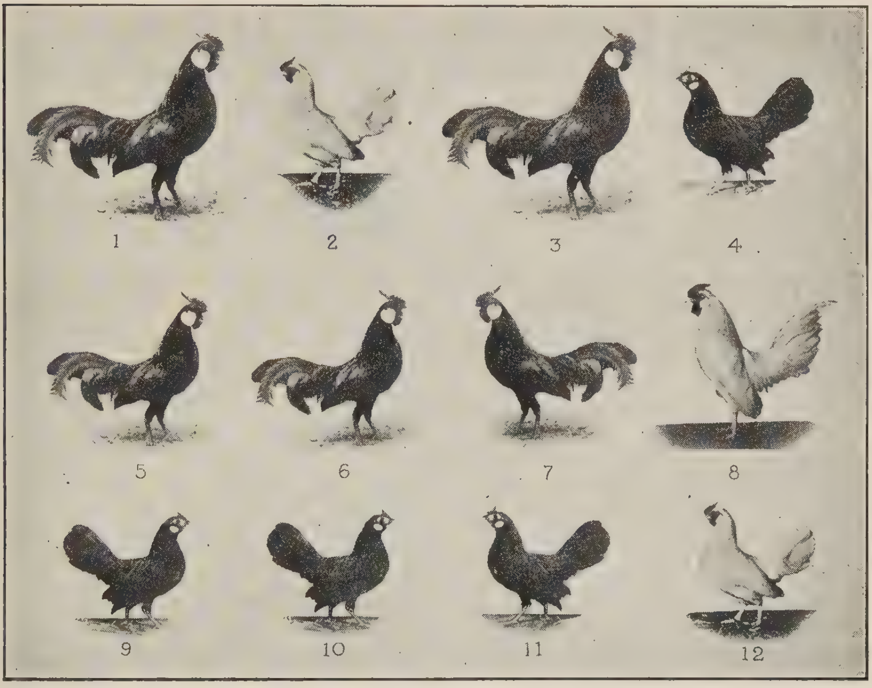


Fig. 27.—A simple case of mendelian inheritance, involving one pair of characters, black and white. Rose-comb Black Bantam male, No. 1, mated to Rose-comb white Bantam female, No. 2, produce all black progeny, as shown in Nos. 3 and 4. When No. 3 and 4 are mated they produce male progeny in the proportion three blacks to one white and female progeny in the same proportion, making three blacks to one white among all of the progeny.

If the original parents had been a Rose-comb White Bantam male and a Rose-comb Black Bantom female, the results would have been the same. (*National Geographic Society. Courtesy National Geographic Magazine.*)

The data in Table 23 give the results secured in matings made by Bateson and Punnett (1908) and in other matings made by Jull and Quinn (1929) at the U. S. Animal Husbandry Experiment Station at Beltsville, Md.

TABLE 23.—PROPORTION OF BLACKS AND WHITES IN THE SECOND HYBRID GENERATION OF MATINGS BETWEEN ROSE-COMB BLACK AND ROSE-COMB WHITE BANTAMS

Author	Number of blacks	Number of whites	Proportion
Bateson and Punnett	70	24	2.92 to 1
Jull and Quinn	320	107	2.99 to 1
Totals	390	131	2.98 to 1

Dominant and Recessive Characters.—There are two points that deserve special consideration. In the first place, the chicks of the first hybrid generation are all black although one parent was white. In the second place, the second hybrid generation always appears in the proportion of three blacks to one white, if sufficient numbers of chicks are hatched. The first phenomenon is called dominance, black being dominant to white in this particular case. White in this case is known as recessive.

The Segregation of Characters.—The second phenomenon illustrates the definite manner in which the two characters segregate in the second hybrid generation. The fact that many characters segregate in inheritance according to definite principles has been demonstrated many times, both with plants and animals. Further illustrations of the segregation of characters in poultry breeding are given in later pages.

It need only be mentioned at this time that characters exist in alternative pairs, such as black and white plumage color in Rose-comb Bantams. The single-comb and the rose-comb represent another pair of alternate characters. There may be a crest or there may be absence of a crest, one character being alternative to the other.

MENDELISM

The segregation of the characters is a phenomenon demonstrated by Mendel in 1865 after 8 years of experimental breeding. Mendel's results were published in 1865 but attracted little attention at the time and remained practically unknown for 35 years until brought to light in 1900 by three investigators. Mendelism simply means the biological theory of heredity first propounded by Mendel, whose first law constitutes the segregation of characters in a definite manner. By following Mendel's method the breeder is able to achieve results much more quickly and with great certainty of securing the desired results because when the genetic constitution of the parents is known, as far as any particular characters are concerned, the results can be predicted in advance.

The Mendelian inheritance of a number of pairs of characters in the chicken has been determined by a number of investigators and some of the results are discussed briefly in order to give the student of poultry husbandry a clearer conception of the genetic constitution of the various breeds and varieties and also to give some conception of the possibility of applying the new knowledge in a practical way.

It is interesting to observe that through the work of Bateson (1902) the chicken was the first animal in which the Mendelian principles of heredity were shown to apply.

More Knowledge Needed.—Hadley (1915) makes the following observation:

> What the poultry world of today needs, in addition to the Standard [of Perfection] which tells how poultry ought to appear is a Standard which will tell *how the varieties ought to breed.* It would be a great help to poultry breeders if each different breed should have its [genetic] constitution represented by a formula designating, so far as possible, all the important characters possessed by that breed, thus indicating the breeding values.

Dominant White.—The White Leghorn is one of the most common fowls in the world and its white color character has been determined by Bateson (1902), Bateson and Punnett (1905, 1906), Hurst (1905), Davenport (1906) and Hadley (1913, 1914 and 1915) and others to be dominant to color. When a White Leghorn is mated to a Black Hamburg, Brown Leghorn, Barred Plymouth Rock or other colored bird, the first generation hybrids are white, although some of the whites may be ticked or splashed black or may show slight indications of barring. This latter phenomenon is explained later, but for the present it is enough to note that the white of the White Leghorn is dominant to color, the reverse of the situation in the Rose-comb Black and Rose-comb White Bantams. When the F_1 birds, from the mating of the White Leghorn and the one of the colored varieties named above, are mated among themselves they produce an F_2 generation of three whites to one colored.

Recessive White.—There are a number of breeds with white varieties in which the white is recessive to color. This condition has been demonstrated in the following cases: White Cochin Bantam by Davenport (1906), White Dorking by Bateson and Punnett (1906), White Langshan by Goodale (1910), White Plymouth Rock by Hadley (1914*a*) and others, White Wyandotte by Lippincott (1919) and others and White Minorca by Punnett (1923). The white character in the White Silkies has been shown to be a simple recessive to color by Bateson and Punnett (1908), Cunningham (1912), Bonhote (1914) and Jones (1921), although the white character is not the same kind that exists in the white varieties mentioned above.

Bare Neck Dominant.—The inheritance of a number of other characters has been determined to follow the Mendelian method. The bare neck, characteristic of the Transylvania Naked-neck breed, has been shown to behave as a simple dominant to normal feathering by Davenport (1914) and Crew (1922*a*). This is a very interesting observation inasmuch as a number of breeders have been exploiting the public by claiming to offer for sale progeny produced from crosses between the turkey and the chicken. So far as known such a cross has never been made and, moreover, if it were possible the hybrids would probably be sterile. What the public has been offered are undoubtedly the progeny matings involving the naked-neck character.

Silkiness Recessive.—Davenport (1906), Bateson and Punnett (1908), Cunningham (1912), Bonhote (1914), Jones (1921), and Dunn and Jull (1927) have demonstrated that the hookless condition of the barbules, which is responsible for the peculiar structure of the plumage of the Silkies breed, behaves as a simple recessive to normal plumage.

Comb Type.—The pea comb, characteristic of the Brahma breed, like the rose comb, is dominant to single comb, as shown by Bateson (1902) and Davenport (1906).

Shank Color.—Lambert and Knox (1927) confirmed the observation of Punnett (1923) and Dunn (1925), who demonstrated that white shank color behaves as a simple dominant to yellow shank color.

The inheritance of a number of other alternative pairs of characters has been studied but, since this book is one dealing with general problems rather than being a text on breeding, further details are omitted.

Genes Give Rise to the Development of Characters.—The various characters which a bird possesses are inherited from its parents. The reproductive organs, or gonads, of the parents produce reproductive cells. The female produces ova or eggs and the male produces spermatozoa. The term "ovum" is the singular of "ova," and the term "spermatozoon" is the singular of "spermatozoa" and each ovum and spermatozoon is a single reproductive cell. The act of fertilization is accomplished through the union of an ovum and a spermatozoon to form the fertilized ovum or egg, which, under proper conditions, develops into a chick.

Gametes and Zygotes.—From the standpoint of reproduction and the inheritance of characters, the reproductive cells are spoken of as "gametes," the term "gamete" meaning a spouse. The ovum is the female gamete and the spermatozoon is the male gamete. The fertilization of the female gamete by the male gamete produces the fertilized egg, which is spoken of as the "zygote," a term meaning yoked together. It is the zygote that develops into the chick.

Chromosomes.—Each gamete contains little thread-like bodies called "chromosomes," which are transmitted from parent to offspring. A fact of fundamental importance is that the number of chromosomes in any given species of animal is constant, as suggested by Agar (1920). The number of chromosomes in the chicken has been studied by Guyer

(1916), Stevens (reported by Boring, 1923), Shiwago (1924) and Hance (1924 and 1926), all of whom observed a relatively large number, a few being large and several very small. Hance (1926) suggests that the number is approximately 35 or 36, and if this proves to be the correct number it is probable that in the female there are 35 and in the male 36 chromosomes.

Sex Chromosomes.—The difference in the number of chromosomes between the male and the female is due to the fact that the male has one more sex chromosome than the female. The sex chromosomes in any species are apparently primarily concerned in the determination of sex, from which they receive their name, while the rest of the chromosomes are called "autosomes" or ordinary chromosomes, and they are always in pairs. The male chicken has 17 pairs of ordinary chromosomes and 2 sex chromosomes, while the female chicken also has 17 pairs of ordinary chromosomes but only 1 sex chromosome.

Sex Inheritance.—It has been pointed out previously that the zygote is the result of the union of the male and female gamete and it has also been pointed out that it is the zygote that develops into the mature chicken. Since the male chicken has 17 pairs of ordinary chromosomes and 2 sex chromosomes, it is obvious that the two gametes that united to produce the zygote that developed into a male must each have contained 17 ordinary chromosomes and 1 sex chromosome. Perhaps an equation would make the matter clear: male gamete with 17 ordinary and 1 sex chromosome + female gamete with 17 ordinary and 1 sex chromosome = a zygote with 17 pairs of ordinary and 2 sex chromosomes, such a zygote being a male. Since the female chicken has 17 pairs of ordinary chromosomes and 1 sex chromosome, it is obvious that of the two gametes uniting to form the zygote, one must have had 17 ordinary and 1 sex chromosome and the other must have had 17 ordinary chromosomes only. In the form of an equation the situation is thus: a gamete with 17 ordinary and 1 sex chromosome + a gamete with 17 ordinary chromosomes = a zygote with 17 pairs of ordinary chromosomes and 1 sex chromosome, such a zygote being a female.

So far, only one phase of the reproductive cycle has been discussed, namely, that of a male gamete uniting with a female gamete to produce a zygote. The other phase of the reproductive cycle consists in the zygotes producing the gametes. Each zygote produces two gametes. The complete reproductive cycle, therefore, consists of gametes uniting to form zygotes and zygotes dividing to produce gametes. The reproductive cycle is illustrated in Fig. 28.

The male zygote containing 17 pairs of ordinary chromosomes and 2 sex chromosomes divides to form 2 gametes, each containing 17 ordinary and 1 sex chromosome. The female zygote containing 17 pairs of ordinary chromosomes and 1 sex chromosome divides to form two different kinds of gametes because one gamete contains 17 ordinary and 1 sex chromosome whereas the other gamete contains 17 ordinary chromosomes only.

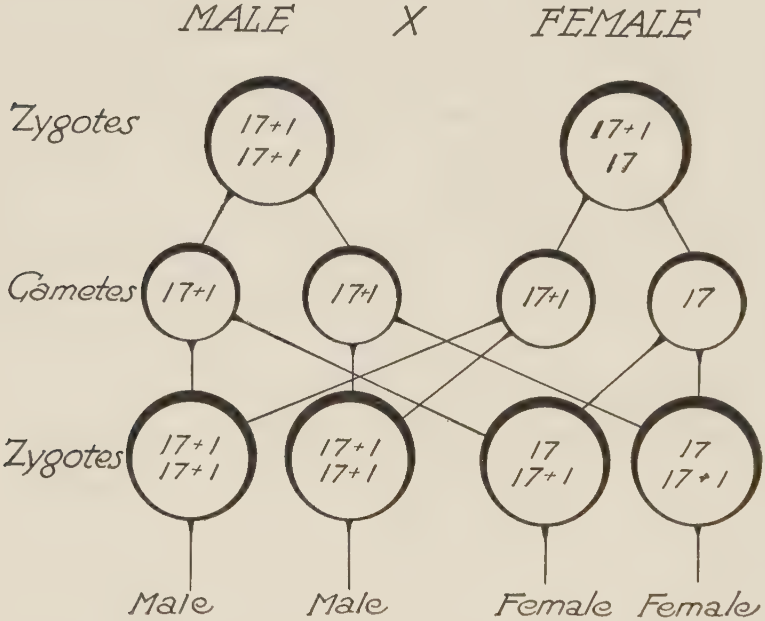


FIG. 28.—The transmission of the chromosomes in the inheritance of sex involves the same principles as the transmission of genes in the inheritance of other characters, such as black and white in Rose-comb Bantam crosses. The male chicken has 17 pairs of antosomes plus 1 pair of sex chromosomes, whereas the female has 17 pairs of antosomes plus 1 sex chromosome. The male produces but one kind of gametes, whereas the female produces two kinds, one with and one without the sex chromosome. The female gamete containing the sex chromosome upon uniting with a male gamete produces a male, whereas the female gamete without the sex chromosome upon uniting with a male gamete produces a female.

Genes.—The chromosomes are the bearers of the hereditary characters but, since there are hundreds of characters but only 17 pairs of ordinary chromosomes and 1 or 2 sex chromosomes according to the sex, it is obvious that each chromosome must be responsible for the development of many characters. Each chromosome is made up of smaller units called "factors" or "genes" (from *gen*, to produce). It is the genes that give rise in development to such characters as black plumage color, barring, single comb, yellow shanks and other characters.

How the Genes for Black and White in Rose-comb Bantams Are Transmitted.—When the fact is appreciated that the genes are responsible for the development of characters and that the genes are component parts of the chromosome, it is a simple matter to trace the transmission of genes from one generation to another.

Since in this cross black is dominant to white, the character black is represented by the capital letter *B* and the recessive character white is represented by the small letter *b*. Furthermore, since genes are responsible for the development of the hereditary characters black and white, they are represented by the letters *B* and *b*, respectively. The ordinary chromosomes, as distinguished from the sex chromosomes, are always in pairs and, since the zygote contains the double or diploid number of chromosomes, the zygote of the Rose-comb Black Bantam contains the genes *BB* and the zygote of the Rose-comb White Bantam contains the genes *bb*. The zygote produces the gametes, which contain the single or haploid number of chromosomes, as shown in Fig. 29. A male gamete unites with a female gamete to produce the new zygote, the first hybrid generation, F_1. In the illustration the letters *B* and *b* represent the genes for black and white, respectively, and, since the inheritance of but one pair of characters is being discussed, the letters *B* and *b* may also be taken to represent the chromosomes carrying the respective genes.

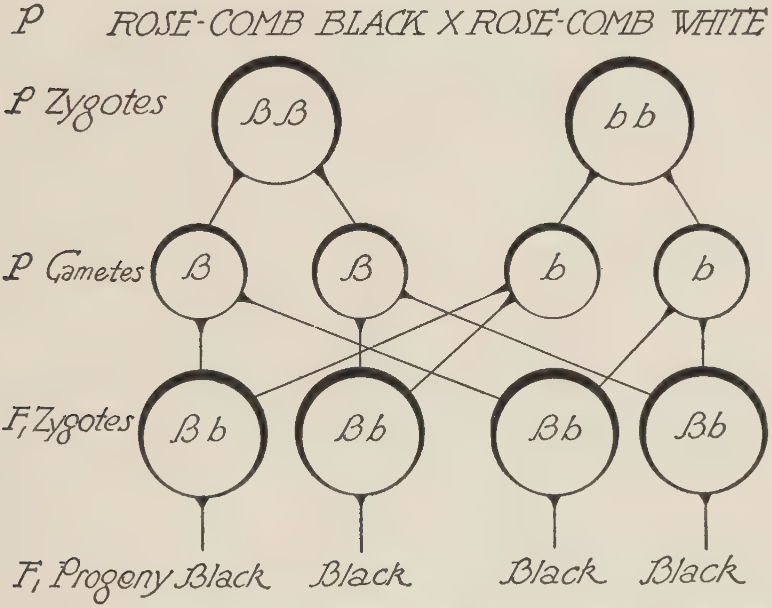


FIG. 29.—The parental zygotes give rise to the parental gametes and the gametes unite in pairs to form the first hybrid generation or F_1 zygotes. The zygotes give rise to the F_1 progeny, which are called "hybrids" in respect to the inheritance of the particular character concerned, and since black *B* is dominant to white *b* all of the progeny are black.

Homozygous and Heterozygous Zygotes.—The birds of the first hybrid generation F_1 are all black, since black, *B*, is dominant to white, *b*. The constitution of the zygote of the black parent is *BB* and this condition is spoken of as being "homozygous" (from *homo*, meaning alike, and *zygous*, referring to the condition of the zygote) which simply means that in this case two similar genes are contained in the zygote. The constitution of the zygote of the white parent is *bb*, this zygote also being in the homozygous condition. On the other hand, the constitution of the zygote of each of the first generation hybrids is *Bb*, and this condition is spoken of as being heterozygous (from *heteros*, meaning different, and *zygous*, referring to the condition of the zygote), which simply means that in this case there are two different genes contained in the zygote.

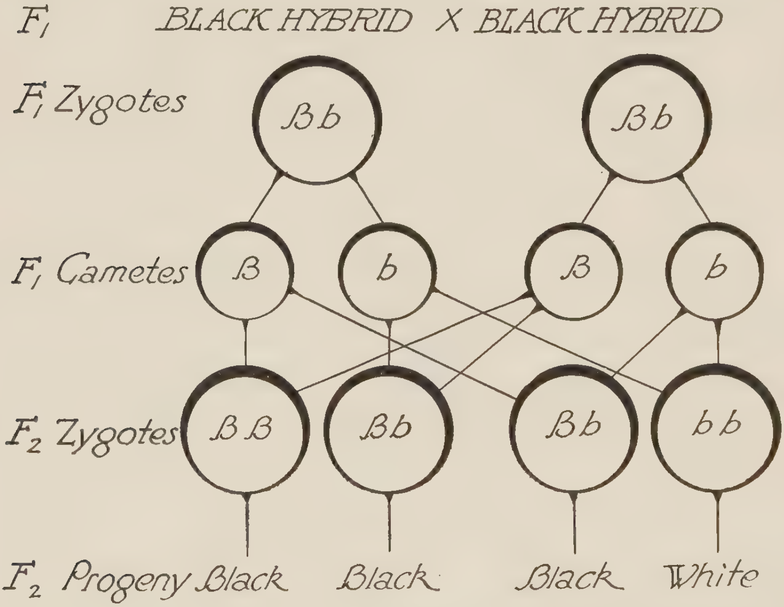


FIG. 30.—The F_1 zygotes give rise to the F_1 gametes, and these gametes unite in pairs to form the F_2 zygotes, which give rise to the F_2 progeny. The color of the progeny is in the proportion of three blacks to one white. It is observed that among the blacks one is homozygous and two are heterozygous for color. The homozygous black and the homozygous white are the same kind of birds as the original parents (see *P* zygotes in Fig. 29).

The Kind of Gametes Formed.—Although the birds of the first hybrid generation resemble the black parents, they do not give the same results in breeding. The F_1 males and females have *Bb* zygotes which produce two kinds of gametes *B* and *b*, as shown below. In the male, therefore, there is an equal number of gametes containing the *B* and the *b* genes, respectively, and in the female there is an equal number of gametes containing the *B* and the *b* genes, respectively. When the male and female gametes unite to form the new zygote, four possible combinations occur in approximately equal numbers, as follows:

B female gamete × *B* male gamete = *BB* zygote—black.
B female gamete × *b* male gamete = *Bb* zygote—black.
b female gamete × *B* male gamete = *Bb* zygote—black.
b female gamete × *b* male gamete = *bb* zygote—white.

A very convenient way of showing the kind of zygotes formed by the gametes is by use of the chequerboard principle. The female gametes are placed opposite the squares on one side of the chequerboard and the male gametes are placed opposite the squares on a diagonal side of the chequerboard. As each gamete of one sex is mated to each gamete of the opposite sex the product is placed in the appropriate square.

		Female Gametes	
		B	*b*
Male Gametes	*B*	*BB* (black)	*Bb* (black)
	b	*Bb* (black)	*bb* (white)

The Kind of Zygotes Produced.—The colors of the progeny arising from the four kinds of zygotes formed are shown in brackets. There are three blacks to one white. One of the blacks, *BB*, is homozygous for the dominant character, while the other two blacks, *Bb*, are heterozygous for each character, and the white, *bb*, is homozygous for the recessive character.

The results in mating birds of the first hybrid generation are illustrated in Fig. 30.

The Second Hybrid Generation.—In the second hybrid generation, F_2, there are three blacks to one white. The first black *BB* is homozygous for the dominant character and always breeds true, that is, when these birds are bred among themselves they produce nothing but blacks, simply because both males and females can only produce gametes containing the *B* gene and when these unite a *BB* zygote is formed. The two blacks in the above illustration each with the *Bb* zygote are heterozygous and produce the same results as their parents, the birds of the first hybrid generation. The white bird, *bb*, is homozygous for the recessive character and when such birds are bred among themselves they produce nothing but whites simply because nothing but *b* genes are formed, and when these unite nothing but *bb* zygotes are formed.

Segregation.—The most important fact to be kept in mind is that in the crossing of two alternative characters, black and white, there results a segregation of the characters in the second hybrid generation in the definite ratio of 3:1, that is, three blacks to one white. From the standpoint of the genetic constitution of the individuals of the second hybrid generation the ratio is really 1:2:1, that is, one homozygous for black, two heterozygous for both characters and one homozygous for white.

Practical Application of Mendelism.—One or two simple examples may be given to demonstrate the practical usefulness of a knowledge of Mendelian inheritance. Suppose a breeder has a flock of Rose-comb Black Bantams which produce a few Rose-comb White Bantams, which are not wanted. From the information presented previously the breeder would know that some of his blacks were heterozygous and, in order to avoid producing whites, the heterozygous blacks would have to be eliminated from the flock. This could be done by pedigree breeding, which would determine which of the blacks were producing the few whites and such blacks could be identified and removed.

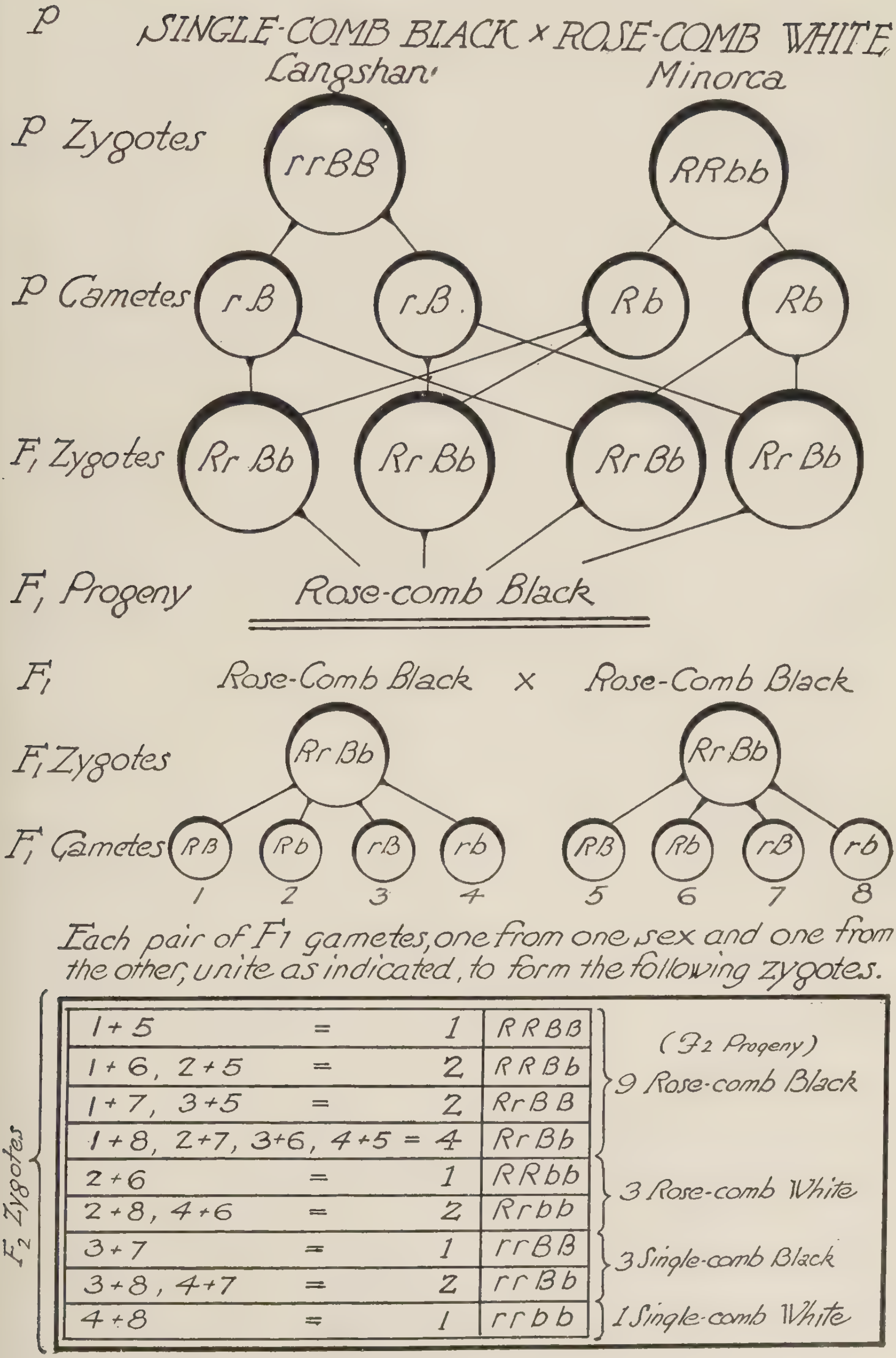
On the other hand, suppose a breeder wished to determine whether a certain Rose-comb Black Bantam were homozygous or heterozygous for black. All he would have to do would be to breed the black to a white and if all the progeny were black the black parent could be regarded as being homozygous, whereas, if blacks and whites were produced in equal proportions, then the black parent must have been heterozygous.

The same principle would apply in respect to the appearance of single combs in a rose-comb breed, like the Wyandottes, single comb being recessive to rose comb. In this case the appearance of single combs demonstrates that two or more of the rose-comb parents were heterozygous and these could be eliminated by pedigree breeding. A rose-comb bird could be determined to be homozygous or heterozygous depending on the results it produced when mated to a single comb bird. The inheritance of rose-comb and single-comb characters is fully discussed and illustrated by Lippincott (1927).

THE INHERITANCE OF TWO PAIRS OF CHARACTERS

The inheritance of two pairs of characters is precisely the same in principle as the inheritance of one pair. Since two pairs of characters are involved, the F_1 hybrids are able to produce four kinds of gametes instead of only two, as in the case of the inheritance of one pair of characters. Since four kinds of gametes are produced by each sex, the possibilities for the segregation and recombination of the chromosomes is four times as great as in the case when only two kinds of gametes are formed, as is shown below.

It has already been pointed out that rose comb is dominant to single comb and that black is dominant to white in certain breeds. Suppose, then, that a Single-comb Black Langshan is mated to a Rose-comb White Minorca and it makes no difference whether the Langshan or Minorca is male or female. By using the appropriate symbols to designate the genes carried in the chromosomes, the mode of inheritance of


P
SINGLE-COMB BLACK × ROSE-COMB WHITE
Langshan
Minorca
P Zygotes
rrBB
RRbb
P Gametes
rB
rB
Rb
Rb
F1 Zygotes
Rr Bb
Rr Bb
Rr Bb
Rr Bb
F1 Progeny
Rose-comb Black
F1
Rose-Comb Black × Rose-Comb Black
F1 Zygotes
Rr Bb
Rr Bb
F1 Gametes
RB
Rb
rB
rb
RB
Rb
rB
rb
1
2
3
4
5
6
7
8
F2 Zygotes

Each pair of F1 gametes, one from one sex and one from the other, unite as indicated, to form the following zygotes.

1 + 5 =	1	RRBB	(F2 Progeny) 9 Rose-comb Black
1 + 6, 2 + 5 =	2	RRBb	
1 + 7, 3 + 5 =	2	RrBB	
1 + 8, 2 + 7, 3 + 6, 4 + 5 =	4	RrBb	
2 + 6 =	1	RRbb	3 Rose-comb White
2 + 8, 4 + 6 =	2	Rrbb	
3 + 7 =	1	rrBB	3 Single-comb Black
3 + 8, 4 + 7 =	2	rrBb	
4 + 8 =	1	rrbb	1 Single-comb White

FIG. 31.—The inheritance of two pairs of characters, showing a 9: 3: 3: 1 ratio in the second hybrid or F_2 generation.

the two pairs of characters is readily demonstrated. Capital letters are used for the dominant characters and small letters for the recessive characters. *R* represents the rose-comb character and the gene that produces it, *r* the single-comb character and the gene that produces it, *B* the black character and the gene that produces it, and *b* the white character and the gene that produces it. Since the chromosomes are borne in pairs, the zygote of the Single-comb Black Langshan contains the genes *rrBB* and the zygote of the Rose-comb White Minorca contains the genes *RRbb*, the Langshan being homozygous for both single comb and black and the Minorca being homozygous for both rose comb and white. The segregation of the chromosomes in the production of the gametes and the recombination of the chromosomes in the production of new zygotes is illustrated in Fig. 31.

The Single-comb Black Langshan parent produces *rB* gametes and the Rose-comb White Minorca parent produces *Rb* gametes; these unite to form the F_1 zygotes *Rr Bb*. Such zygotes are heterozygous for both pairs of characters but the presence of *R* and *B* makes the F_1 birds rose-comb blacks. The F_1 male zygote produces four kinds of gametes *RB*, *Rb*, *rB*, *rb*, and, likewise, the F_1 female zygote produces the same four kinds of gametes *RB*, *Rb*, *rB*, and *rb*. Each male gamete may mate with

	Female Gametes			
Male Gametes	*RB*	*Rb*	*rB*	*rb*
RB	*RRBB* (rose-comb black)	*RRBb* (rose-comb black)	*RrBB* (rose-comb black)	*RrBb* (rose-comb black)
Rb	*RRBb* (rose-comb black)	*RRbb* (rose-comb white)	*RrBb* (rose-comb black)	*Rrbb* (rose-comb white)
rB	*RrBB* (rose-comb black)	*RrBb* (rose-comb black)	*rrBB* (single-comb black)	*rrBb* (single-comb black)
rb	*RrBb* (rose-comb black)	*Rrbb* (rose-comb white)	*rrBb* (single-comb black)	*rrbb* (single-comb white)

each female gamete so that there are 16 possible combinations. The chequerboard plan of illustrating the kind of zygote formed by the mating of any two gametes is very effective.

Of the 16 zygotes formed it is observed that they give rise to 9 rose-comb blacks, 3 rose-comb whites, 3 single-comb blacks and 1 single-comb white, a 9:3:3:1 ratio. If comb alone is considered, however, it is apparent that there are 12 rose combs and 4 single combs, a 3:1 ratio. Also, if color alone is considered it is seen that there are 12 blacks and 4 whites, a 3:1 ratio. That is, for either pair of characters considered separately, a 3:1 ratio results, as in the case of the inheritance of black and white in the Rose-comb Bantams.

Considering the two pairs of characters in combination leads to interesting observations. Of the 16 F_2 birds, 12 are black, of which 9 are rose combs and 3 are single combs, a 3:1 ratio. Of the 16 F_2 birds, 4 are white, of which 3 are rose combs and 1 is a single comb, a 3:1 ratio.

It should also be observed that of the 16 zygotes formed, one is homozygous for both rose comb and black color and one is homozygous for both single comb and white color; these zygotes are different from those of the original parents and of the F_1 generation and could only have been produced through the random assortment of the chromosomes. It is apparent that the 9:3:3:1 ratio in the F_2 generation is precisely what should be expected when each of two pairs of characters are inherited independently of each other.

In the preceding illustration, one of the parents, the Single-comb Black Langshan, has the recessive comb character and the dominant color character, while the other parent, Rose-comb White Minorca, has the dominant comb character and the recessive color character. Suppose, however, that the parents had been a Single-comb White Langshan and a Rose-comb Black Minorca, then what would have been the results in the F_1 and F_2 generations? The parental zygotes would have been *rrbb* for the Single-comb White Langshan, and *RRBB* for the Rose-comb Black Minorca. The gametes formed would have been *rb* and *RB*, respectively, and the F_1 zygotes would have been *RrBb*, the same as in a mating between a Single-comb Black Langshan and a Rose-comb White Minorca. The F_2 zygotes would have been just the same as in the first mating and a similar 9:3:3:1 ratio would have been produced. In other words, as far as the principle of the assortment of the chromosomes is concerned it makes no difference from which parent the characters have come.

Independent Assortment of Genes.—The independent assortment of the genes was first demonstrated through the brilliant work of Mendel so many years ago and became what is known as Mendel's second law. His results showed that when races differ from each other in two pairs of characters, each pair gives a 3:1 ratio when considered by itself and the inheritance of one pair is independent of that of the other. It should be borne in mind that without random assortment of the chromosomes carrying the genes the birds of the F_1 generation could each produce two kinds of gametes with four possible combinations so that the F_2 generation would comprise a 3:1 ratio, that is, one each of the grandparental types and two of the F_1 type.

Since the phenomenon of the random assortment of the chromosomes is so fundamentally important to a proper understanding of the principles of inheritance, the situation is further explained by the use of symbols. It has already been noted that in the cross between the Single-comb Black Langshan and Rose-comb White Minorca the F_1 birds each produced four kinds of gametes *RB*, *Rb*, *rB* and *rb* and this made possible 16 combinations. If random assortment of the chromosomes did not take place, the F_1 birds would produce two kinds of gametes only, *rB* and *Rb*, and these would produce one *rrBB* zygote, two *RrBb* zygotes and one *RRbb* zygote. The first zygote would produce a Single-comb Black Langhan, the second two zygotes would produce birds similar to their hybrid parents, and the last zygote would produce a Rose-comb White Minorca. It has been shown, however, that, in actual breeding operations, a 9:3:3:1 ratio is produced, and it follows, therefore, that random assortment of the chromosomes takes place. Moreover, since the assortment of the chromosomes is random, it should be observed that the chromosomes go through a reduction division in one of the numerous stages through which they pass in the course of their development. This furnishes the mechanism required by Mendel's law in so far as the character pairs lie in different chromosome pairs.

Concerning the inheritance of two pairs of characters, it should be pointed out that certain modificatious of the 9:3:3:1 ratio sometimes arise as the result of different genes producing a like effect or as the result of two different genes having a complementary effect on each other when brought together. Bateson and Punnett (1906) mated White Dorkings, in which white is recessive to color, to Silkies, in which white is also recessive to color, and found that the F_1 generation was composed of colored birds only while the F_2 generation was composed of 9 colored to 7 white birds in every 16, a ratio of 9:7. This is merely a 9:3:3:1 ratio in which the last three classes cannot be distinguished from each other. Two genes are involved, one of which acting upon the other produces color, though neither by itself is able to produce color. Nine zygotes produced in the F_2 birds contain both genes, and the birds arising from such zygotes are colored, while the other seven zygotes contain one or the other gene, or neither, as could be readily shown by constructing the chequerboard mating scheme, and, consequently, the seven birds are all white. Other modifications of the 9:3:3:1 ratio include the following: 9:3:4, 12:3:1, 13:3 and 15:1, but lack of space prevents a discussion of these cases.

THE INHERITANCE OF SEVERAL PAIRS OF CHARACTERS

Where more than two pairs of characters are involved and the different genes producing the characters are on different chromosomes, the segregation and independent assortment of the characters behave in precisely the same way as in the inheritance of one pair or two pairs of characters. It will be recalled that in the case of one pair of characters there are two kinds of F_1 gametes formed and in the case of two pairs of characters there are four kinds of F_1 gametes formed. The number of different kinds of gametes formed by the F_1 birds is doubled with every increase in the number of different genes involved. In the inheritance of three pairs of characters there are 8 kinds of F_1 gametes formed and in the inheritance of four pairs of characters there are 16 kinds of F_1 gametes formed. Each time the different genes involved is increased by one, the number of F_1 gametes formed is increased by two. On the other hand, for each increase in the number of different genes involved, the number of F_2 individuals required to be produced to secure the appearance of the various combination of characters resulting from the chance combination of the different kinds of F_1 gametes is increased by four, as shown in Table 24.

TABLE 24.—SHOWING, FOR EACH INCREASE IN THE NUMBER OF DIFFERENT GENES CARRIED ON DIFFERENT CHROMOSOMES, THE NUMBER OF KINDS OF F_1 GAMETES FORMED, THE F_2 RATIO, AND THE NUMBER OF F_2 INDIVIDUALS NECESSARY TO SECURE THE APPEARANCE OF ALL POSSIBLE COMBINATION OF CHARACTERS

Number of different genes carried on different chromosomes	Number of different kinds of F_1 gametes produced	The F_2 ratio	Number of F_2 individuals necessary to secure the appearance of all possible combinations of characters
1	2	3:1	4
2	4	9:3:3:1	16
3	8	27:9:9:9:3:3:3:1	64
4	16	81:27:27:27:27:9:9:9:9:9:9:3:3:3:3:1	256

Various Genes Produce Different Effects.—Many genes produce definite effects and lead to the development of specific characters such as black color, single comb and rose comb. There are other genes which through interaction upon each other produce an effect that leads to the development of a specific character. An interesting example of such a case is the production of colored birds only from a mating between a White Wyandotte and a White Silkie. The appearance of colored birds in this mating is the result of the interaction of the two genes for white, each coming from a different breed. Such genes are known as complementary genes. Asmundson (1926) has shown that side sprigs are due apparently to the presence of two non-sex-linked dominant genes that are complementary in their action.

The character white in White Leghorns is dominant to the color character in other breeds. The case of the White Leghorn is very interesting, however, since it carries a gene for color though it also contains a gene which inhibits the development of color and is thus a white bird. The White Leghorn contains an inhibiting gene and the presence of such a gene has been demonstrated in other cases.

Multiple genes are those whose cumulative effects produce a specific character, such as size of bird.

There are genes which produce an intensifying effect upon a certain color and there are genes which tend to produce a diluting effect upon a given color and such genes are referred to as intensifiers and diluters, respectively.

There are still other genes that give rise to the extension of pigment in certain birds, as shown by Lippincott (1921), Dunn (1923*b*) and Knox (1927) and other genes that restrict the pigment to certain areas or sections of the feather, as shown by Dunn (1923*b*).

LINKAGE AND CROSSING OVER

The previous discussion in this chapter has assumed that in the inheritance of one or more pairs of characters, the genes producing the characters were carried on different chromosomes. The assumption is correct for the particular characters considered but, at the same time, it is realized that the chicken possesses many more characters than chromosomes, from which it follows that many genes must be carried on the same chromosome. Winge (1919) has pointed out that no case is known in which the number of simultaneously and independently segregating pairs of characters existing together in one individual exceeds the haploid chromosome number of the species. Therefore, the number of independently segregating pairs of characters in the case of the chicken—with only 17 chromosomes as the haploid number, disregarding for the time being the sex chromosomes—must be relatively small as compared with the number of pairs of characters that do not undergo independent assortment.

Linkage.—Numerous investigators in studying the inheritance of characters in both plants and animals have demonstrated in many matings that characters from one individual tend to remain together in later generations. Such characters although undergoing independent assortment to a greater or less extent in the F_2 generation, tend to remain linked together, giving rise to the term "linkage." In view of this fact it is appreciated that Mendel's second law, establishing the independent assortment of the chromosomes, has a limited application. The tendency shown by many characters to be linked together in successive generations rather than assort freely varies from one extreme where the characters hold together completely to the other extreme where the characters show only a slightly greater probability of holding together than of assorting freely.

Very little is known regarding linkage in poultry and it is beyond the province of this book to discuss details except in so far as it is necessary to present the fundamental features of the mechanism of heredity, of which linkage is an important aspect. Using symbols to represent genes, suppose the genes A and B each stand for a dominant character and a and b each for the recessive character. If a bird homozygous for both A and B ($AABB$) is mated to another bird homozygous for both a and b ($aabb$), the gametes AB unite with the gametes ab to produce F_1 zygotes $AaBb$. If there is no linkage between the genes, the F_1 zygotes produce four kinds of F_1 gametes in equal numbers, as discussed and illustrated in a previous section of this chapter. If there is linkage between the genes A and B, then the F_1 zygotes produce four kinds of F_1 gametes *but not in equal numbers.* The two parental types of gametes AB and ab are more numerous than the two non-parental types Ab and aB. In this case linkage exists between the genes A and B, on the one hand, and between a and b, on the other. Conversely, if the parental gametes are Ab and aB (parents $AAbb$ and $aaBB$, respectively), then, of the four kinds of F_1 gametes produced, the parental types of gametes Ab and aB are more numerous than the non-parental types AB and ab. In this case linkage exists between A and b and between a and B.

Goodale (1917) and Haldane (1921) demonstrated the existence of linkage in the case of the chicken and more recently Dunn and Jull (1927) demonstrated the existence of linkage between the genes for rose comb and for crest. F_1 males heterozygous for rose comb and crest were mated to females recessive for both characters, that is, single-comb non-crested females, and the backcross generation produced 55 rose-comb crested birds, 36 single-comb crested, 39 rose-comb non-crested and 55 single-comb non-crested. The parental types used in the first mating were rose-comb crested mated to single-comb non-crested, and so it is observed that there were more of the parental types produced than of the non-parental types when the backcross was made. It should be pointed out that the crucial test in determining the presence of linkage is to mate the F_1 individuals to the parent that is homozygous for both the recessive characters, such a mating being called a "backcross."

The phenomena of linkage cannot be discussed further except to say that it may be demonstrated to have considerable practical significance in poultry breeding, as explained by Punnett (1923):

> The discovery of the phenomenon of linkage, and the development of its possibilities now being realized, indicate a shorter and more subtle method of attack upon some of the genetic problems that are uppermost in the mind of the man who makes his living out of poultry. Visible characters, whether of structure or plumage, are relatively easy to deal with: invisible characters, such as fecundity, broodiness, hatchability, stamina, and the like, are notoriously difficult to analyse and to control. But if we can, through linkage, relate the invisible with the visible, the task of analysis becomes immeasurably lightened, and the possibility of control is brought appreciably nearer.

Crossing Over.—Crossing over of the genes is a correlative aspect of linkage and, among others, the results of Serebrovsky (1922) and Agar (1924) might be cited. Linkage implies that the linked genes lie so close to each other in the same chromosome that they are transmitted together from generation to generation. Breeding experiments with certain animals have demonstrated that the genes are borne in the chromosomes like beads in a string and that each pair of genes occupies the same relative position in each pair of chromosomes. For instance, the gene *R*, producing the dominant rose-comb character, occupies the same relative position in the chromosome of the male or female as the gene *r*, producing the recessive single-comb character, occupies in the chromosome of the opposite sex. So also with all other pairs of genes; they each occupy the same relative positions in the respective pairs of chromosomes that carry them, except in cases of sex linkage discussed later.

The chromosomes from one parent may carry the genes *AbCd* and the chromosome from the other parent would then carry the genes *aBcD*, and *A* and *a* would occupy the same relative position in each chromosome and, likewise, with *B* and *b*, *C* and *c* and *D* and *d*. Now, if *A* and *b* are near together in one chromosome, so *a* and *B* would be as close together in the other chromosome. Also, if *c* and *D* are some distance apart in the one chromosome, so *C* and *d* would be the same distance apart in the other chromosome. As far as the phenomenon of crossing over is concerned, it is obvious that crossing over is more likely to occur between two pairs of genes that are some distance apart than when they are close together. Among the genes referred to above, therefore, crossing over is more likely to occur among the *cD* and *Cd* pairs of genes than among the *Ab* and *aB* pairs of genes.

SEX-LINKED INHERITANCE

Up to the present the inheritance of characters has been discussed with respect to those characters which are inherited equally from sire and dam.

Such characters are borne on the 17 pairs of ordinary chromosomes common to both sexes, in any single individual half of the ordinary chromosomes being of maternal origin and half of paternal origin. There are certain characters, however, which are inherited only from dam to son. These are called "sex-linked" characters and the genes producing them are borne on the sex chromosomes.

Barring a Sex-linked Factor.—Cushman (1893) was probably the first to report the phenomenon of sex linkage. He mated Indian Game males to Barred Plymouth Rock females and observed that the sons of this mating were barred while the daughters were for the most part black and were entirely free of barring. Punnet and Bateson (1908) and Spillman (1908) were the first to explain the inheritance of the barring character on a sex-linked basis.

The results of a mating between a Black Langshan male and a Barred Plymouth Rock female are illustrated in cross 1 in Fig. 32. The F_1 males are barred and the F_1 females are black or largely so. When the F_1 birds are mated among themselves, half of the F_2 males are barred and half are black, half of the F_2 females are barred and half are black.

The results of a mating between a Barred Plymouth Rock male and a Black Langshan female are illustrated in cross 2, in Fig. 32. The F_1 males and females are all barred. When the F_1 birds are bred among themselves, all of the F_2 males are barred but half of the F_2 females are barred and half are black.

The explanation of such an interesting situation is very simple. It will be recalled from the discussion in the fore part of this chapter that the male chicken has two sex chromosomes while the female has only one sex chromosome. In the case of the chicken the inheritance of sex characters is commonly referred to as the WZ type because the symbol Z is used to denote the presence of the sex chromosome and W the absence of the sex chromosome. The male zygote, ZZ, has two sex chromosomes and, therefore, produces Z gametes. The female zygote, WZ, has one sex chromosome and, therefore, produces W gametes and Z gametes in approximate equality. Sex-linked genes, being borne on the sex chromosomes only, are contained in the Z gametes only, the W gamete having no sex chromosome and, therefore, containing no sex-linked genes. The gene for barring is contained only in the Z gametes and is, therefore, sex linked as the illustration in Fig. 32 demonstrates.

The inheritance of barring as a sex-linked dominant character has been demonstrated by Goodale (1909 and 1910), who used several different breeds, Pearl and Surface (1910*a* and 1910*b*), Holdefleisz (1911), Morgan and Goodale (1912), Hadley (1914*a*), Frateur (1914) and others. The inheritance of the spangled pattern of the Silver Spangled Hamburg has been reported to be sex linked by Lefevre and Rucker (1923). The inheritance of rate of feathering in a cross

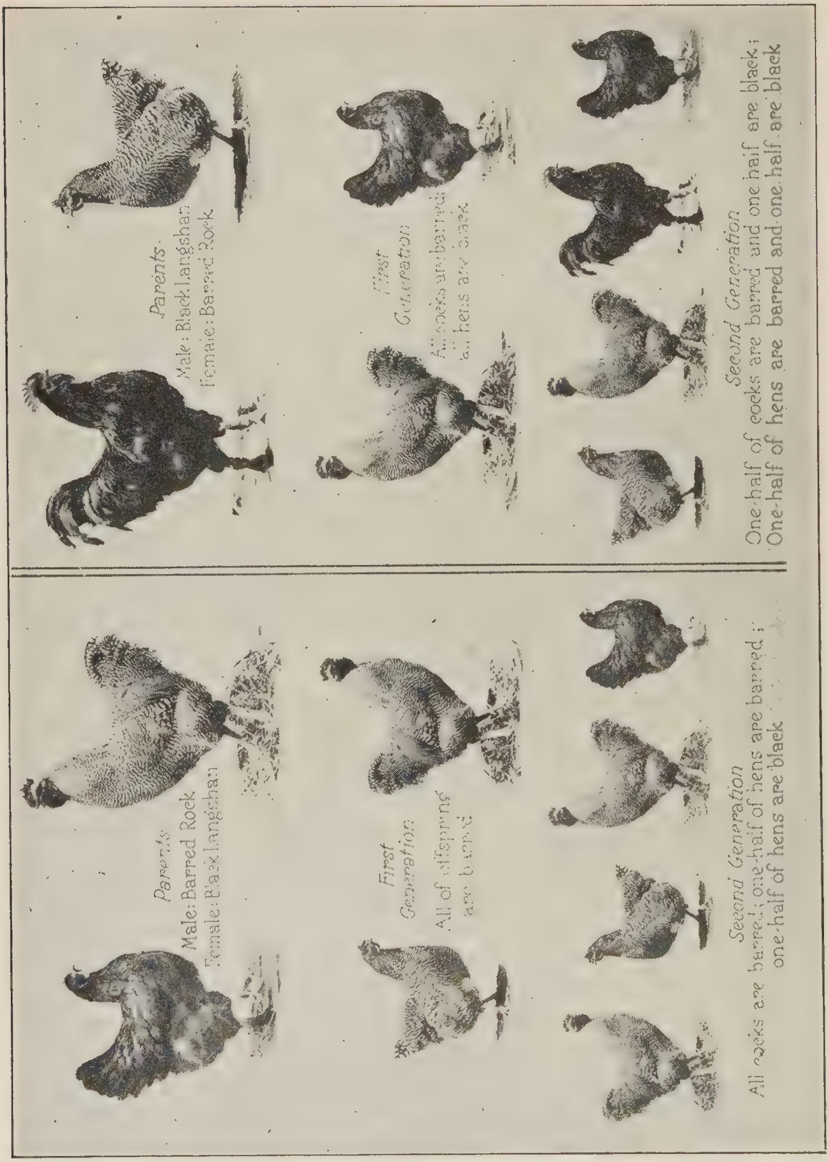

Parents
Male: Barred Rock
Female: Black Langshan
First Generation
All of offspring are barred
Second Generation
All cocks are barred; one-half of hens are barred;
one-half of hens are black
Parents
Male: Black Langshan
Female: Barred Rock
First Generation
All cocks are barred;
all hens are black
Second Generation
One-half of cocks are barred and one-half are black;
One-half of hens are barred and one-half are black

FIG. 32.

between Single-comb White Leghorn and Jersey Black Giant has been demonstrated by Warren (1925) to be sex linked.

Sex Linkage in Shank Color.—White Plymouth Rocks should have yellow shanks, but occasionally females appear having greenish-yellow shanks, which are undesirable. Hays (1927*a*) has explained the inheritance of the off-colored shanks on a sex-linked basis, a knowledge of which should enable the breeder to eliminate the character from his strain of White Plymouth Rocks.

Practical Application of Sex Linkage.—Sex-linked inheritance has a practical value in poultry breeding in enabling the sexes of chicks to be separated at hatching time. For instance, if a Black Langshan, Rhode Island Red or Brown Leghorn male is mated to Barred Plymouth Rock females, at hatching time the male chicks have a white spot on the back of the head and yellow shanks while the female chicks are solid black in down color and have black shanks. Dunn (1923*a*) and Jull (1924*b*) have discussed this subject fully and Punnett (1923) has shown that in crosses between Light Sussex females and Brown Leghorn males, Silver Campine females and Buff Orpington males, and between Silver Laced Wyandotte females and Buff Orpington males the sexes can be distinguished quite readily at hatching time, the males being much lighter in color than the females.

SECONDARY SEXUAL CHARACTERS AND THEIR DEVELOPMENT

In all breeds of chickens the males have more prominently developed comb and wattles and tail feathers than the females. Spurs are found on the shanks of males and rarely occur in females. Also, in most breeds the hackle and saddle feathers of the male are longer and more pointed than in the female. These characters are called "secondary sexual" characters and serve as a ready basis of distinction between male and female.

Growth.—When a normally feathered male is castrated, or caponized, to use the more common term, the bird undergoes marked changes and if kept long enough will grow larger than if not caponized. Titus and Jull (1928) have shown that the rate of growth of capons proceeds at the same rate as their brother cockerels up to the time the cockerels reach maturity, but that the capons thereafter continue to increase in size.

Combs, Wattles and Spurs.—Upon being caponized the comb and wattles and the spur fail to develop as in cockerels. Souba (1923*a*)

FIG. 32.—This illustration of sex-linked inheritance shows the results that always occur in certain crosses. It will be observed that in the mating on the left the barred cock has transmitted his barred character to all his daughters, sons and grandsons, and to one-half of his granddaughters, whereas the black hen has transmitted her color to none of her sons, daughters, or grandsons, and to only one-half of her granddaughters; but in the mating on the right all the pullets of the first generation are black and all the cocks are barred. The breeder, who knows the mode of inheritance of certain color factors, can mate his birds in such a manner as to distinguish the sex of his chicks as soon as they are hatched. The factor for barring is sex-linked. (*National Geographic Society. Courtesy National Geographic Magazine.*)

observed a correlation between size of the testes or male gonads and the comb in Single-comb White Leghorn cockerels though Greenwood and Crew (1927) found no such relationship in a group of abnormal males. Champy (1926) introduced a thin slice of the testis into the combs of each of three capons and observed a regrowth of comb equal to that of a normal male. The results of other experiments by Pezard, Sand and Caridroit (1926) and by Caridroit and Pezard (1926) and others have been claimed to demonstrate that the male gonad produces a secretion called a "hormone." Crew (1925*a*), however, secured results that do not support the contention.

Removal and Transplantation of Gonads.—The effects of ovarian transplantation in chickens have been studied by Guthrie (1910) and Davenport (1911) and the complete removal of the ovary and testes as well as ovarian and testicular transplantations have been studied by Goodale (1913, 1916*a*, 1916*b*, 1916*c*, and 1918*a*) whose results showed briefly that when the ovary is completely removed from the female she acquires male characteristics, and when the testes are removed from the male and ovarian tissue is transplanted the male assumes the characteristics of the female as far as comb, wattles and plumage are concerned. Gates (1918) describes a White Wyandotte which was a normal hen for two years and then through the degeneration of her ovary acquired male characteristics, including crowing. Cole and Lippincott (1919) describe a female whose ovary developed a tumor, giving rise to the development of male plumage and that when a portion of normal ovary was transplanted on the affected ovary, normal female plumage resulted.

Pezard (1915) found that removal of the ovary caused the female to develop spurs, while Goodale (1922) was able to obtain, by selection, a strain of fowls in which the females were spurred.

Henny Feathering.—The relationship between the secondary sexual characters and the effects of secretions produced by the gonads, the ovary and testes, becomes more complex when the henny feathered condition of the males of such breeds as Campines and Sebright Bantams is considered. Morgan (1919*a*) suggested that hen feathering in males is due to the action of an internal secretion produced by the "luteal" cells of the gonad but the results of Pease (1921), Fell (1923) and Greenwood (1925) show that such is not the case, and Nonidez (1924*b*) held that the condition is produced by the physiological action of some of the endocrine glands, particularly the thyroid and pituitary. The breeding results of Punnett and Bailey (1921) and the results of Torrey and Horning (1922 and 1925), Cole and Reid (1924), Zavadovsky (1925), Brambell (1926), Buchanan (1926), Hutt (1927) and Crew (1927*a*) all go to show that there is a relationship between gonad and thyroid in respect to plumage characterization. Crew (1925*b*) suggests that the effect of gonad on plumage is not direct but is secondary to the effect of gonad on thyroid, which is genetically different in those breeds in which the males are normally hen feathered as compared with other breeds in which the males are normally cock feathered.

Giacomini (1924) observed a loss in the pigmentation of feathers when birds were fed dessicated thyroid. Crew (1922*b*) describes a Black Leghorn which turned white, the change being due apparently to an altered condition of the adrenal gland. Lippincott (1920) describes a Blue Andalusian hen which turned white but continued to breed as a typical blue bird, from which it is apparent, though not discussed, that a disturbed condition of one or more of the endocrine glands produced the change in plumage color.

The above cases have been cited, without discussing details, to impress upon students of poultry husbandry the complex problems involved in the inheritance of the secondary sexual characters and to convey some idea of the significance of the secretions of the endocrine glands in avian physiology.

CHAPTER IX

THE INHERITANCE OF EGG PRODUCTION

The results of investigational work conducted over a period of years have demonstrated that egg production is inherited just as plumage color and structural differences are inherited. Egg production, therefore, may be regarded as a character, but its inheritance is much more complex than in the case of the inheritance of black and white or comb form.

A Complex Problem.—A study of the inheritance of egg production presents a very complex problem because of the number of factors involved. Not only must laying performance, which in itself is affected by a number of physiological factors, be observed over a period of at least a year, but other matters must also be considered, such as the size and standard quality of the birds and the size of egg. These considerations are necessarily involved because the breeding stock produced must embody certain minimum qualifications in order to be of the greatest practical usefulness. The problem is a very broad and complex one and, because of the practical importance of the inheritance of egg production, it is given a separate chapter in this book.

Selection in Breeding.—Future progress in breeding for increased egg production depends largely upon the poultry breeder's ability to control heredity, and heredity can be controlled and directed best only when the knowledge of poultry breeders develops sufficiently to enable them to select breeding stock that will transmit to their offspring the most desirable qualities. *Selection* is the keynote in the program of future development. The refinement of methods of selection, therefore, is a very important problem confronting poultry breeders of today.

Poultry breeding as an industry lies at the foundation of poultry husbandry and the many diversified standard breeds and varieties of domestic chickens which have been produced from a very small number of originally ancestral forms is striking evidence of the degree to which man has developed and extended his control over the natural processes of reproduction. It is a truism that man's fancies have led to the production of many of the standard breeds and varieties of chickens known to us today, and the satisfaction of having developed something new has constituted one of the best stimuli in man's efforts to understand the laws of inheritance. In a practical world, however, which we find ours to be, there has been a growing demand for the production of chickens that meet man's needs as well as his fancies. The production of eggs and poultry meat becomes of more importance as the human population increases. Therefore, more and more is the poultry breeder confronted with the question: How can he best select and breed his chickens for the production of offspring possessing the most desirable qualities? It is obvious, in answer to this question, that the rather haphazard and empirical methods of procedure in breeding poultry must be superseded by thorough and systematic studies of the inheritance of factors associated with egg and poultry meat production.

Heredity and Environment.—Inheritance has always been of primary importance in providing variations for purposes of selection, although the influence of environment is by no means insignificant. Best results in the development of heavy laying strains, for instance, can only be achieved when the laying stock is housed most adequately, fed most efficiently and otherwise provided with the most suitable environmental conditions. On the other hand, the most efficient methods of feeding the most adequate rations will probably never result in any marked development of laying ability if the genetic factors for high fecundity are not present in the stock. In discussing human heredity, Prof. Karl Pearson and his collaborators have said: "It is five to ten times as profitable for a child to be born of parents of sound physique and of brisk, orderly mentality, as for a child to be born and nurtured in a good physical environment." Regardless of whether it is possible to discriminate so precisely between the influence of environment and inheritance in respect to fecundity in the domestic fowl, it is apparent that the first and most important determinant of fecundity is inheritance.

Selection by Appearance.—Realizing, then, that a system of breeding for the development of a heavy laying strain involves the fundamental principles of inheritance, it is necessary to inquire concerning practices followed and results achieved by poultry breeders. With few exceptions, the practice of poultry breeders has consisted of selecting the *best looking* males to mate to the *best looking* females, on the theory that "like tends to beget like." The degree of success achieved under this system of breeding is shown by the very slow progress made in increasing the average egg production per bird for the country as a whole, and, again, by the results in particular flocks where special efforts have been made to secure anticipated results. Attention is directed to the findings of Dunn (1924*b*) in connection with the trend of annual egg production as shown by egg-laying contest results over a period of nine years. It is shown for the breeds analyzed that there is little material change in average annual egg production per bird.

Pearl and Surface (1909*b*), in the case of egg production in fowls, and Pearl (1910*b*), in the case of milk production in cattle, have shown that the selection of breeders based on their appearance proved to be an exceedingly unreliable guide to real breeding worth.

Egg Production Inherited.—The excellent work of Gowell in breeding Barred Plymouth Rocks for increased egg production at the Maine Experiment Station is well known to the poultry world. Gowell (1902, 1903), through his failure to increase egg production over a period of nine years by practicing the selection of breeders each year based on total first-year production of the ancestors, laid the foundations for later work which was to demonstrate the value of the progeny test.

Fig. 33.—The Georgia National Egg-laying Contest. An officially conducted egg-laying contest is a means of testing the laying ability of a portion of a breeder's flock. Laying contests have done much to stimulate interest in the various factors involved in developing high-laying strains. (*Photograph by Ga. State Agr. Coll.*)

An analysis of the first-year egg production records of White Leghorn dams and daughters entered in egg laying contests in New Jersey led Hervey (1925*a*) to conclude as follows:

> Viewed strictly as a mass proposition, in no instance is it possible to show an existing relationship between the production of daughters and their sires' dams or between daughters' and dams' production. This is of practical significance because there is more or less common practice of purchasing males for breeding purposes according to the magnitude of the trap-nest records of their mothers. The present data indicate that such a record is of no great importance unless something more is known of the ancestry.

On the other hand, Harris and Lewis (1923*a*), in an analysis of the first- and second-year egg production records of dams in relation to the first-year records of daughters in another group of New Jersey White Leghorn contest pullets, conclude that:

> The coefficients measuring the relationship between the first year records of the mothers and the first year records of the daughters, and those measuring the relationship between the second year records of the mothers and the first year records of the daughters are positive in sign and are probably statistically signifi-

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cant in comparison with their probable errors. They indicate, therefore, the possibility of some increase in production by the selection of the higher producing mothers in a contest population.

This observation tends to show that mass selection might be expected to increase the level of fecundity from year to year but progress would probably be rather slow and uncertain.

Progeny Testing Important.—Hays (1922) reports concerning the results established by Goodale in breeding Rhode Island Reds for increased egg production that the performance of the daughters of any sire serves as a criterion in determining his breeding work. In discussing the problem of mass selection versus progeny performance selection, Gowen (1924*a*) maintains that in the breeding of both plants and animals it is only when progeny performance selection is practiced that material progress can be expected. Furthermore, among the investigators, the results of Pearl (1912*a* and *b*), Goodale (1919) and Dryden (1921) clearly demonstrate the value of progeny performance selection in the development of heavy laying strains.

Several Inheritance Factors Involved.—Not only has it been demonstrated that egg production is inherited, Pearl (1912), Goodale (1918*b*), Goodale and MacMullen (1919), Hurst (1921) and Hays (1924), but it has also been demonstrated that a number of factors are involved. The complexity of the situation arises from the fact that annual records of egg production are affected by such factors as the time elapsing between date of hatching and date of laying the first egg, the intensity of production from the time the first egg is laid, the amount of broodiness, the persistency of production during the summer and fall months of the first-year's production, which in turn is probably associated with the onset of the first annual molt. These and other factors may operate in devious ways to affect egg production even among uniformly bred birds kept under as nearly ideal conditions as possible. The inheritance of a number of the factors has been established upon a fairly definite basis and the balance of this chapter is devoted to a discussion of the results secured.

The Inheritance of Sexual Maturity.—The fact should not be overlooked that sexual maturity, as indicated by the age at which a pullet commences laying, may be something quite different from somatic maturity, as indicated by the time a pullet attains maximum body weight. Rice (1915) has shown, in the case of White Leghorn pullets, that there is an important relationship between earliness of maturity and rate and persistency of production. Kempster (1922, 1925*a*, 1926*a* and 1927) reports that there is a significant negative correlation between sexual maturity and egg production for the first laying year. In other words, Kempster found that quick maturing pullets tend to make the highest annual records. Similar observations have been made by Ball and Alder (1917), Kennard (1921), Hervey (1923*a*), Hays and Bennett (1923), Hays, Sanborn and James (1924), Jull (1923*a*, 1924*b*), Parkhurst (1926) and Buster (1927) in the case of White Leghorns, Rhode Island Reds and Barred Plymouth Rocks. On the other hand, Lippincott, Parker and Schaumburg (1925), in a group of White Leghorn pullets, found no correlation between earliness of sexual maturity and annual egg production, but it is interesting to note that the White Leghorns whose records were studied were a selected group. Kempster points out that out of a flock of 120 birds the 60 which were culled at the end of 240 days required 20.05 ± 3.86 days longer to mature than did those which were retained by Lippincott, Parker and Schaumburg because of their superior ability to produce eggs. Harris and Lewis (1923*b*) observed that birds that commence to lay early are in general long persistent layers. Hays and Sanborn (1927*b*), however, have found that "the high yearly producer must be early maturing not because early maturity itself is of importance but because early maturity has some 'association' with high intensity and very intimate 'association' with persistency."

Early Maturity Desirable.—On this or any other basis, earliness of sexual maturity is a very desirable character and, since it is inherited, as demonstrated by Hays (1924–1925), it can be bred into a flock by selecting as breeders each succeeding year the progeny of females that matured early, especially if they also showed high intensity and persistency. In Rhode Island Reds, Hays found that the inheritance of earliness of maturity, birds commencing to lay in less than 215 days of age, depends upon two pairs of genes, one pair of which is sex linked. The dominant gene of either of the two pairs of genes is capable of inducing earliness of maturity. The genes are designated E and e, dominant and recessive, respectively, for one pair and E^1 and e^1, dominant and recessive, respectively, for the other pair. Both pairs are transmitted to both sexes by males, but the pair E and e is transmitted by females only to their sons and is therefore sex linked.

The Inheritance of Intensity of Laying.—The intensity of laying refers to the rate of production from the time that laying commences. Intensity of laying may be expressed in terms of percentage production, which is determined by multiplying the actual production by 100 and dividing the product by the number of days involved. Intensity may be determined on the basis of cycles, litters or clutches, all of which are explained on page 71, but from the standpoint of determining the relative significance of intensity in relation to annual production it is customary to determine intensity on the basis of cycles of production.

Are There Cycles of Production?—It has been the custom to divide a bird's annual egg record into four rather arbitrary periods—winter, spring, summer and fall—or sometimes the last two periods are taken together. These are called "cycles of production" and, for some years after the first work on the inheritance of egg production was begun, it was felt that the winter cycle was the most significant in determining the inherent laying capacity of a bird. Ball and Alder (1917), however, after a comprehensive study of records of production in White Leghorns, reported by Ball, Turpin and Alder (1914) and Ball, Alder and Egbert (1916), believed that the winter cycle does not represent correctly a biological entity. They also feel that a record of production of three years is a safer guide than the record for the pullet year only in determining the inherent laying ability of a bird. Harris and Lewis (1922*a*), from an analysis of records of production in White Leghorns, conclude that "there is no evidence of special factors which distinguish the 'winter cycle' from any other period of the year." Then, again, Dunn (1924*b*, 1927*a*) found no evidence of definite cycles of production in Plymouth Rocks, Rhode Island Reds, Wyandottes, and White Leghorns entered in the Storrs egg laying contest over a period of nine years. Nevertheless, practically all recent studies on the inheritance of egg production have been based on the pullet record and the winter cycle has been shown to be of particular significance. It is possible, of course, that the results concerning the inheritance of intensity which have been found to apply to the winter cycle may also apply to other cycles and to the annual record taken as a whole.

Sex-linked Inheritance of Production.—The foundation of the present knowledge of the inheritance of intensity of laying was laid by the intensive studies of Pearl (1909*b*, 1911, 1912*a*, 1912*b*, 1915*a*, 1915*b*). Using the winter cycle, to Mar. 1, of the pullet year, as a basis for the analysis of records of production in Barred Plymouth Rocks, Pearl proposed a theory to explain the inheritance of winter production. The theory rested upon a sex-linked basis, two pairs of genes being involved, L_1 and l_1 being the dominant and recessive genes, respectively, of the pair located on one of the ordinary chromosomes, and L_2 and l_2 being the dominant and recessive genes, respectively, of the pair located on the sex chromosome. Pearl postulated that if a bird carried L_1 but not L_2, it would lay slightly less than 30 eggs up to Mar. 1, whereas if a bird carried L_2 but not L_1, it would also lay less than 30 eggs up to Mar. 1, but that if a bird carried both L_1 and L_2 it would lay more than 30 eggs up to Mar. 1. Since L_2 is sex linked, it is apparent that dams could transmit it only to their sons, or as Pearl says, "high fecundity is not inherited by daughters from their dam."

It is not surprising that such an interesting theory of the inheritance of winter egg production should stimulate further inquiry along similar lines, particularly since Pearl believed that his results applied to annual production as well as winter production. Goodale (1916*d*, 1918*b*, 1918*c*, 1919) Goodale and MacMullen (1919) and Goodale and Sanborn

(1922) in an analysis of the records of production in Rhode Island Reds observe that Pearl's theory of the inheritance of fecundity is inadequate. They believe that annual egg production depends on several more or less independent pairs of genes and that similar records of production may result from the action of different pairs of genes. Goodale and Sanborn finally developed the view that annual production is determined by the combined action of five characteristics, each produced by one or more pairs of genes, the five characteristics being sexual maturity, intensity of laying, amount of broodiness, winter pause in laying and persistency of production in the summer and fall of the pullet year. The problem of the inheritance of sexual maturity has already been discussed, and the characteristics broodiness, winter pause and persistency are discussed later in their appropriate sections.

Importance of Intensity.—The breeding work with the Rhode Island Reds upon which Goodale reported his results was continued by Hays, who observes (1924–1925) that intensity of laying is inherited, intensity being measured in egg production from the time that laying commences to Mar. 1. On this basis it was found that the birds could be divided into two major groups according to whether a production of 50 per cent was obtained. Two pairs of genes are involved, R and r, and R^1 and r^1, and a production of over 50 per cent is attained when the two dominant genes R and R^1 are together in the same bird. They are regarded as being complementary genes.

The Inheritance of Broodiness.—Among the various breeds of chickens, some exhibit much more broodiness than others. The Leghorns, for instance, exhibit very little broodiness, whereas Plymouth Rocks, Rhode Island Reds, Wyandottes and Orpingtons frequently exhibit much broodiness, especially if they have not been bred for egg production.

The inheritance of broodiness was studied by Goodale, Sanborn and White (1920) who found two pairs of complementary genes, A and a and C and c, to be involved. Broodiness is due to the presence of both dominant genes A and C, neither of which is sex linked, according to Hays (1924–1925). Punnett and Bailey (1920) observe that more than one independent dominant gene could produce broodiness but do not believe that the genes involved are complementary. Hays, however, has substantiated the views expressed by Goodale et al. and Hays and Sanborn (1926, 1927*a*) point out that the degree of broodiness as well as the presence or absence of broodiness during the pullet year of production must be considered in the breeding program and that there is a somewhat higher winter intensity in broody than in non-broody individuals. Hays and Sanborn (1927*b*) emphasize the importance of selecting as breeders non-broody pullets that have a high winter intensity of production.

The Inheritance of Winter Pause.—Long, continuous records of egg production are the exception rather than the rule, even in strains that have been bred for egg production for several years. Broodiness naturally makes a break in the record of production, but independent of this characteristic, Goodale (1918*c*) observes that many of his Rhode Island Reds exhibited a characteristic winter pause which lasted from a few days to as much as two months or more. Hays (1924–1925) found that the flock could be divided into two groups, those which exhibited a pause and those which did not, and from breeding results demonstrated that the winter pause is inherited and is due to the presence of a dominant gene M, which is not sex linked, from which it follows that birds showing a non-pause must be of the mm type, since the genes are borne in pairs. Hays and Sanborn (1927*b*) found no apparent association between winter pause and intensity. It is clear, however, that the greatest progress in breeding for increased egg production can only be secured when birds showing little or no winter pause are used as breeders.

The Inheritance of Persistency of Production.—So far the discussion has indicated the desirability of earliness of sexual maturity, high winter intensity, non-broodiness, and no winter pause in the breeding of birds for increased egg production. Still another characteristic is desirable. Observations of practical poultry breeders and the results of investigational work have shown that usually the best layers in a flock are those which persist in production during the late summer and fall months of the pullet year of production.

Harris et al. (1917, 1918, 1921, 1922) have shown that birds having the highest annual records are those which usually lay best during the autumn of the first year of production. Regarding the relative significance of the four cycles of production—winter, spring, summer, and autumn—Harris and Lewis (1923*c*) observe a more intimate relationship between the autumn cycles of the dams and the autumn cycles of the daughters than between the dam and daughter cycles for the other periods of the year. Furthermore, Hays and Sanborn (1927*b*) found a very intimate relationship between persistency of production and annual production. Since persistency of production is so important, it is interesting to note that Hurst (1925) suggests that persistency is inherited and that Hays (1927*b*) has shown that high persistency is inherited in the ordinary Mendelian manner, the dominant gene P giving rise to persistency. Hays also points out that P is intimately associated with E^1, previously described as the dominant non-sex-linked gene for early sexual maturity. It is apparent, therefore, that in order to develop a heavy laying strain, birds homozygous for P and for E^1 are necessary.

The Inheritance of Annual Egg Production.—In so far as the theories of the inheritance of the numerous characters affecting annual egg production, as developed largely by Goodale and Hays, represent a true picture of the problem, it is apparent that eight pairs of genes are involved. They are as follows:

Characteristic	Dominant gene	Recessive gene	Sex linked or non-sex linked
Early sexual maturity	E	e	Sex linked
	E^1	e^1	Non-sex linked
Intensity	R	r	Non-sex linked
	R^1	r^1	Non-sex linked
Broodiness	A	a	Non-sex linked
	C	c	Non-sex linked
Winter pause	M	m	Non-sex linked
Persistency	P	p	Non-sex linked

Since the genes are borne in the chromosomes which are in pairs, one of each pair of paternal and the other of maternal origin, it is obvious that a male homozygous for all eight desirable genes would have the constitution $EE\ E^1E^1\ RR\ R^1R^1\ aaccmmPP$ and the best kind of a female would have the constitution $E\text{-}E^1\ E^1\ RR\ R^1R^1\ aaccmmPP$, being homozygous for all genes except the sex-linked gene E. The production of individuals possessing the combination of genes shown above is realized as a difficult and complicated task for the simple reason that, when eight pairs of genes are involved, the number of possible combinations is very large, with the result that the number of birds necessary to make the proper matings to determine the genetic constitution of any particular individual would be very large indeed. On page 103 is given the number of possible combinations in the F_2 generation when four pairs of genes are involved, from which some conception may be gained of the magnitude of the problem when eight pairs of genes are involved.

The Inheritance of Long-time Production.—Studies on the inheritance of egg production have been in relation to the first-year production almost entirely, in which respect first-year production has been considered to be composed of four definite cycles—the winter cycle from November to February, inclusive, the spring cycle from March to May, inclusive, the summer cycle from June to August, inclusive, and the fall cycle including September and October. That the first-year production should be divided into four such arbitrary periods seems very questionable in the light of recent studies. Brody (1921), from an analysis of the first-year records of production of 4,210 Barred Plymouth Rocks at the Maine Agricultural Experiment Station and 1,000 White Leghorns in the Storrs egg laying contests, determined that egg production is of the same general order as the growth of organisms. The curve constructed by Brody shows no indications of cycles of production.

Nature of First-year Production.—Harris and Lewis (1922*a*), in analyzing the first- and second-year records of production of 443 White Leghorns in the Vineland egg laying contest found no evidence of special factors which distinguish the winter cycle of production from that of any other period of the year. Moreover, Harris, Kirkpatrick, Blakeslee, Warner and Card (1921), from an analysis of the first-year production records of 1,840 Storrs contest White Leghorns, Harris, Kirkpatrick, and Blakeslee (1921), in the case of 415 Storrs contest White Leghorn first-year records, Harris and Goodale (1922), in the case of 1,658 first-year records made by Rhode Island Reds at the Massachusetts Agricultural Experiment Station have shown that the annual egg record of a series of birds may be predicted with a reasonably high degree of accuracy when their production for a single month is known. They have also shown that a somewhat higher accuracy of prediction is possible when the production of two or more months is taken into consideration. These findings tend to support Brody's observation and indicate the absence of specific cycles of production, but show rather that from the time that laying commences there is a methodical rate of production until cessation of the first-year production.

First- and Second-year Production.—That there is a sensible correlation between first-year production and second-year production has been clearly demonstrated, although the opinions held by early workers varied considerably. Gowell (1903), in the case of Barred Plymouth Rocks at the Maine Experiment Station, observed that birds that laid approximately 120 eggs in the first year lay satisfactorily during the second year, but birds that laid 100 eggs or less in the first year laid poorly during the second year. Pearl and Surface (1909*d*), from data of 66 Barred Plymouth Rocks, observe that there is no sensible correlation between first- and second-year records. Nixon (1912), in the case of 88 White Leghorns, found a significant correlation between first-year production and second-year production and between second-year production and third-year production. Ball, Turpin and Alder (1914) analyzed the records of White Leghorns kept over a period of years and made the following observation: "The total production of a flock for the first three years appears to be the same regardless of whether the first year record was extremely high, extremely low, or medium in amount." A similar observation was made based upon further studies of the same flock of White Leghorns by Ball, Alder and Egbert (1916) and by Ball and Alder (1917). Ball et al. believed that studies on the inheritance of egg production should be based on the egg production of the first three years at least.

Harris and Lewis (1922*b*), in respect to the first two years of production in 443 Vineland contest White Leghorns, observed a material relationship between the average production of the flock in the second year and the average production in the first year. They also found that the time of beginning of laying and of cessation of laying in the two years is evidently correlated and that not only is the production of every individual month of the second year correlated with that of every individual month of the first year, but that the correlations between the monthly productions of the first year and the annual productions of the second year are positive and statistically significant, a fact confirmed by the same authors later (1922*c*). Further analysis of the records led the same authors (1923*b*) to conclude that birds which are precocious layers are in general long, persistent layers and that those birds which are most persistent in laying at the close of the first year are the most precocious in the resumption of laying activities in their second year. Harris (1926) concludes that the first two years of a bird's life may be regarded as a unit.

Decline in Second-year Production.—Brody, Henderson, and Kempster (1923) have shown that each year's egg production is 88 per cent of the preceding year's production. In other words, a first-year production of 200 eggs would be followed by a second-year production of 176 eggs and

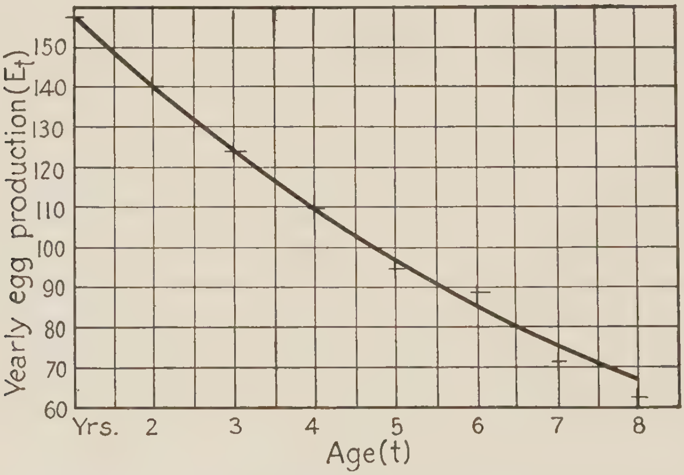

FIG. 34.—The decline in egg production with age in the domestic fowl. The smooth line represents the computed values; the crosses represent the observed values. The observed values during the seventh and eighth years are not reliable owing to the small number of individuals represented in the averages. (*After Brody, Henderson and Kempster.*)

a first-year production of 100 eggs would be followed by a second-year production of 88 eggs. The decline of egg production with age is shown in Fig. 34. This observation is not in accord with the opinions expressed by Ball and Alder (1917) to the effect that "The distribution of production does not seem to be at all affected by age up to three years at least, but total production affects distribution regardless of age." It should be noted, however, that an examination of the records of production upon which the observation of Ball and Alder was based show that for the most part the first-year records were somewhat lower, on the average, than in the case of other records of production upon which different observations have been drawn by various workers.

In view of the indefinite situation concerning the observations of various investigators on the relationship between first-year production and the production of subsequent years, it was felt to be very desirable to examine available data with the view of determining as precisely as possible the extent to which first-year production may be taken as a criterion of production in subsequent years. This is an important practical problem, first, from the standpoint of eliminating from the flock those birds which obviously could not be expected to produce at a profit in their second and later laying years and, second, from the standpoint of adopting a suitable standard for the second-year production when the standard adopted for the first year production is 200 or more eggs.

The data in Table 25 show the second-year production as a percentage of first-year production in a number of breeds and varieties. The records of Bittenbender, Hays, Lunn, Mussehl, and Payne were kindly furnished by correspondence; the records of Lewis, Hannas and Wene (1919) were obtained from their report of the Vineland International Egg-laying and Breeding Contest, running from Nov. 1, 1916 to Oct. 31, 1918; the records of Harris and Lewis (1922*a*) were based on 443 White Leghorns entered in the contest mentioned previously; the records of the B.A.I. were obtained at the U. S. Animal Husbandry Experiment Station at Beltsville, Md.

It will be seen that in only two cases is the second-year production percentage as high as the figure (88) reported by Brody, Henderson and Kempster (1923), their figure having been determined on the first-year production of 158 eggs per bird for 222 birds of two breeds (names of the breeds not mentioned) and the second-year production of 140 eggs per bird for 221 birds of the same two breeds. The data in Table 25 show a range of second-year production percentage from 60.97 to 124.79. It should be noted that the two highest second-year percentages, 124.79 and 116.81, are based on first-year production records of 117.00 and 119.00 eggs, respectively. The rest of the second-year percentages range from 60.97 to 83.98 and, it should be noted in their cases that the first-year production per bird ranged from 144.30 to 257.00.

High first-year production does not seem to be definitely associated with high or low second-year production percentage or *vice versa*. It should be borne in mind, of course, that the records of Lewis, Hannas and Wene and those of Harris and Lewis are contest records, while all the other records are from experiment station flocks and undoubtedly represent selected birds, selected on the basis of first-year records. The contest records were obtained, moreover, from Nov. 1 to Oct. 31, each year,

TABLE 25.—SECOND-YEAR EGG PRODUCTION AS A PERCENTAGE OF FIRST-YEAR PRODUCTION IN VARIOUS BREEDS OF THE DOMESTIC FOWL

Breed and variety	Authority	Year	Number of birds	Average production per bird		Second-year production as a percentage of first-year production
				First year	Second year	
Barred Plymouth Rocks	Bittenbender	1928	48	160.71	134.96	83.98
Barred Plymouth Rocks	Mussehl	1928	50	216.00	131.70	60.97
Barred Plymouth Rocks	Lunn	1928	146	228.42	164.71	72.11
Barred Plymouth Rocks	B.A.I.	1928	37	220.76	148.54	67.29
White Plymouth Rocks	Bittenbender	1928	89	174.07	114.43	65.74
Plymouth Rocks	Lewis, Hannas and Wene	1919	170	155.00	119.10	76.84
Rhode Island Reds	Bittenbender	1928	124	183.97	120.15	65.31
Rhode Island Reds	Hays	1928	450	219.48	139.08	63.37
Rhode Island Reds	Payne	1928	32	197.00	139.00	70.56
Rhode Island Reds	Mussehl	1928	50	217.40	153.60	70.65
Rhode Island Reds	Lewis, Hannas and Wene	1919	80	150.60	117.20	77.82
Rhode Island Reds	B. A. I.	1928	75	205.69	151.43	73.62
White Wyandottes	Bittenbender	1928	64	186.31	124.63	66.89
White Wyandottes	Mussehl	1928	16	202.40	137.40	67.89
Wyandottes	Lewis, Hannas and Wene	1919	150	144.30	115.40	79.97
White Leghorns	Ball, Alder, Egbert and Turpin	1914	58	117.00	146.00	124.79
		1916	29	119.00	139.00	116.81
		1916	100	153.00	101.00	66.01
White Leghorns	Bittenbender	1928	910	210.30	152.82	72.67
White Leghorns	Harris and Lewis	1922*a*	443	174.05	139.79	80.32
White Leghorns	Lunn	1928	103	232.81	171.44	73.64
White Leghorns	Mussehl	1928	50	218.70	169.10	77.32
White Leghorns	Payne	1928	32	257.00	173.00	67.32
White Leghorns	B. A. I.	1928	73	227.60	183.23	80.51
Leghorns	Lewis, Hannas and Wene	1919	600	169.70	137.60	81.08

while experiment station records in probably all cases (though not stated in correspondence) were obtained from date of first egg to 364 days thereafter for the first year and 365 days thereafter for the second year.

It should also be borne in mind that the management of the stock affects production in both years regardless of the genetic constitution of the stock. Lunn, for instance, explained that his birds were given a rest after the cessation of their first-year production. It is believed, however, that the data in Table 25, secured from widely scattered sections of the country, show what may be expected in respect to second-year production as a percentage of first-year production under average conditions, especially in respect to selected stock.

In order to test the matter further, the first-year records of production of the Vineland contest birds were divided into three classes, 0–100 eggs, 101–201 eggs and 202–302 eggs, and the average production per bird for each class was obtained as shown in Table 26. For the sake of convenience the three classes are called "low," "medium" and "high." For each first-year production class the average production per bird for the second year was obtained as well as the second-year production as a percentage of first-year production, as shown in Table 26. Such an analysis of the data should show whether birds that are low producers in the first year show the same second-year percentage as birds that are high producers in the first year.

TABLE 26.—SECOND-YEAR EGG PRODUCTION AS A PERCENTAGE OF LOW, MEDIUM AND HIGH FIRST-YEAR PRODUCTION, RESPECTIVELY, IN FOUR BREEDS OF THE DOMESTIC FOWL

Breed	First-year production class	Number of birds	Average production per bird		Second-year production as a percentage of first-year production
			First year	Second year	
Plymouth Rocks..	0–100	22	79.68 ± 3.290	97.32 ± 6.257	130.32
	101–201	124	151.95 ± 1.638	119.24 ± 2.739	78.47
	202–302	24	231.38 ± 3.898	129.50 ± 5.889	55.97
Rhode Island Reds.	0–100	11	76.36 ± 5.728	64.18 ± 7.945	84.05
	101–201	60	150.72 ± 2.426	120.82 ± 3.882	80.16
	202–302	9	220.33 ± 3.549	141.44 ± 7.546	64.19
Wyandottes.......	0–100	28	65.71 ± 3.633	89.89 ± 6.130	136.80
	101–201	110	151.06 ± 1.733	117.18 ± 3.090	77.57
	202–302	12	222.08 ± 2.757	139.25 ± 7.459	62.70
Leghorns..........	0–100	33	65.45 ± 3.407	104.91 ± 5.739	160.29
	101–201	438	159.01 ± 0.826	131.45 ± 1.159	82.67
	202–302	129	225.24 ± 1.096	159.47 ± 2.339	70.80

From the data in Table 26 it will be seen that in the case of each breed the second-year production as a percentage of first-year production is highest in the low first-year production class, next highest in the medium first-year production class, and lowest in the high first-year production class. In other words, birds which lay less than 100 eggs in the first year tend to lay more in the second year, the only exception being in the case of the Rhode Island Reds, in which case there were very few birds. Medium first-year producers, birds averaging about 150 to 160 eggs, made a second-year production of about 78 to about 82 per cent of the first-year production. In other words, the Plymouth Rocks, Rhode Island Reds and Wyandottes which laid approximately 150 eggs per bird in the first year laid approximately 120 eggs per bird in the second year and the Leghorns which laid approximately 160 eggs per bird in the first year laid approximately 130 eggs per bird in the second year. The high first-year production class, birds averaging about 220 to 230 eggs, made a second-year production of about 56 to about 71 per cent of the first-year production. The second-year production percentage of the first-year production was lower in the case of the three American breeds than in the case of the Leghorns. It is apparent, therefore, that the higher the first-year production the greater is the relative decrease in second-year production.

Taking into consideration the observation of Harris (1926) that the first two years of a bird's life may be regarded as a unit, the records of the Vineland contest birds have been analyzed on the basis of second-year production as a percentage of the two-year production. The data are shown in Table 27 for the low, medium and high first-year production classes in each of the four breeds.

Table 27.—Second-year Egg Production as a Percentage of the Two-year Production in Four Breeds of the Domestic Fowl

First-year production, class	Second-year production			
	Plymouth Rocks	Rhode Island Reds	Wyandottes	Leghorns
0–100	54.61 ± 2.623	45.68 ± 4.922	55.34 ± 2.883	58.62 ± 2.396
101–201	42.40 ± 0.684	42.83 ± 1.082	41.83 ± 0.760	44.60 ± 0.254
202–302	35.13 ± 1.020	38.64 ± 1.445	37.87 ± 1.258	40.78 ± 0.432

When the two-year record of a bird is considered, it is seen from Table 27 that: (1) more than half of the eggs are laid in the second year in the case of low first-year producers, except in the case of the Rhode Island Reds where but few records are involved; (2) from about 42 to about 45 per cent of the eggs are laid in the second year in the case of medium first-year producers; (3) from about 35 to about 41 per cent of the eggs are laid in the second year in the case of high first-year producers.

The analysis of the records of egg production presented previously makes clear why the opinions of a number of early workers varied in respect to the relationship between the first two years' production. Some of the early workers based their opinions on results secured from low first-year producers. Low first-year production may be due to a variety of causes; the birds may not possess the proper genes for high egg production or, if they possess them, the birds may have caught a cold, or they may have acquired chicken pox, or they may have become heavily infested with worms, or a host of other factors might have intervened to prevent the birds from laying the number of eggs their genetic constitution would permit.

It will be recalled that except in the cases of relatively low first-year production none of the figures of second-year production expressed as a percentage of first-year production is as high as that given by Brody, Henderson and Kempster (1923). In other words, the decline in egg production observed by these three investigators was not as great as that found in the case of practically all birds discussed here. This is interesting because it may mean that the Brody, Henderson and Kempster stock was genetically superior from the standpoint of maintaining egg production at a high level from one year to another.

Another important observation brought out in this discussion is that a standard of approximately 150 eggs for the second-year production is a relatively high standard when the first-year minimum standard is 200 eggs and the same is true in respect to a standard of 160 eggs for the second year when the first-year standard is based on a minimum of 225 eggs.

Egg production on a two-year basis would appear to be a better basis for the selection of the best breeders than first-year production alone. In view of the observation of Harris and Lewis (1923*b*) that those birds which are most persistent in laying at the close of the first year are the most precocious in the resumption of laying activities in their second year, it is apparent that the intensity of production during the fore part of the second laying year is an excellent criterion for determining the laying ability of birds on a two-year basis.

To whatever extent the ability to lay well over a period of years can be developed in a flock by selection and breeding, to that extent the annual cost of reproducing the flock annually will be reduced. The inheritance of long-time production is of immense practical importance and is deserving of much more consideration than it has received up to the present.

Importance of Constitutional Vigor.—The ability to produce well over a period of years makes it imperative that the layers possess an abundance of constitutional vigor. The layers must possess the ability to withstand the strain of heavy production. Pearl (1913) has emphasized the importance of constitutional vigor and Rogers (1912, 1914) has shown that selection at the beginning of the second year is of equal importance with that of the first year. Pearl (1923) has emphasized the importance of constitutional vigor in respect to longevity and has determined in the case of one animal that duration of life is inherited. Applying his observations to poultry he says:

> If I were in a position to do so I should like to try, for a period of years, the experiment of breeding each year the *oldest* hens, which could be had, and from which it was possible to get any chicks at all. To ensure a reasonable degree of fertility, I should use younger male birds. Such offspring as were obtained would be kept as a wholly separate flock and line bred, working in all the time as much "high longevity" blood as possible.
>
> I feel confident, from what little I know of the biology of poultry, on the one hand, and the duration of life, on the other hand, that after about five years I

> should have a flock of poultry of astonishingly strong constitutions, extremely low chick mortality, and, I think, high productiveness.

It can be said with definite assuredness, at any rate, that the problem of the inheritance of long-time production is of great practical importance and should receive the fullest possible consideration on the part of poultry breeders.

The Inheritance of Egg Size, Shape and Shell Color.—The preceding discussion has considered the inheritance of egg production on the basis of total number of eggs laid irrespective of their size, shape or color. In practical breeding work, however, it is becoming more important to produce eggs of a minimum size only, since eggs are being sold by weight as well as by count. It is becoming more and more the practice to sell eggs on a graded basis, size being an important factor in grading. Shape and color are also important factors in grading, inasmuch as eggs of one grade must be reasonably uniform in size, shape and color. Moreover, the shape of eggs is also of practical importance since many hens lay long, narrow eggs which are inclined to break when packed in cartons and cases. The inheritance of the three factors, size, shape and color of eggs is a problem of practical importance.

Egg Size.—The inheritance of egg size has been investigated to a slight extent only, and much more needs to be done before definite conclusions can be drawn. Factors affecting the mean weight of the first-year production of a bird are numerous, as pointed out on page 71, making it a very difficult problem to determine the nature of the inheritance of egg size. Benjamin (1920) found that small size of egg in White Leghorns is apparently dominant to large egg size. Hurst (1921) made the same observation concerning the inheritance of egg size in other breeds. Kopéc (1924), in crosses between Leghorn males and Polish "Grünfüssler" (green-footed) females, found evidence of the inheritance of egg size, small size being dominant to large size.

Hays (1929) makes the following observations regarding the inheritance of egg weight, his observations being based on weights of eggs as laid from the time laying commenced in each pullet up to Jan. 1:

> The wild ancestor, *Gallus bankiva*, of the domestic hen lays a very small egg, probably not exceeding 40 g. On the other hand, most of the present-day pure breeds of poultry produce eggs rather closely approximating 56.7 g., but the number of eggs is not great unless the hens are bred for heavy laying. Very frequently small-egg size is a concomitant of heavy laying, particularly in early maturing flocks, as Jull has pointed out. What is the situation from the genetic standpoint?
>
> It appears probable that in the evolution of modern breeds of poultry, a gene for large-egg size (B) has been reasonably well "fixed" by breeders, so that the average hen now lays a moderate number of large eggs but is not necessarily homozygous for gene B. These data also indicate that minor modifiers of egg

size are operating, so that the range above 52 g. as shown by these data is rather wide. These modifiers may be both physiological and hereditary, but are of minor significance in comparison with gene *B*. In the second place, a dominant gene (*A*) for small-egg size (below 56.7 g. by Mar. 1) has appeared. The gene *A* behaves as epistatic to gene *B*, consequently those individuals carrying both genes *A* and *B* will lay small eggs. Those birds carrying *A* alone lay smaller eggs than those carrying both genes (*A*, *B* birds), and those lacking both (*aabb* birds) lay very small eggs. Only *aB* birds lay "standard" eggs.

The probable genotypes for egg size are as follows:

aabb *AAbb* *Aabb*	47 g. or under up to Jan. 1.
AABb *AaBb*	48 to 49 g. up to Jan. 1.
AABB *AaBB*	50 to 51 g. up to Jan. 1.
aaBB *aaBb*	52 g. or over up to Jan. 1.

These represent the four major classes of pullets with respect to egg weight used in these studies. Class 1 is made up of those pullets that lay eggs weighing 47 g. or under up to Jan. 1. The range in this group is wide because it is made up of three genotypes. In class 2 the range is 48 to 49 g. Class 3 has a range from 50 to 51 g. Class 4 includes all pullets whose eggs averaged 52 g. or more up to Jan. 1. This last class ranges from 52 to 60 g., and this wide range is evidently produced by several variables, only one of which (dominant gene *B*) has been considered in these studies. For the purpose of this work, namely, to discover the major genetic differences between birds laying 56.7 g. eggs by Mar. 1 and those laying eggs smaller than 56.7 g., it seems justifiable to refer to the above four classes of layers as phenotypes (recognizable classes). In this report, therefore, but one large-egg class is considered, while three small-egg classes are discussed. The fact that gene *A* is epistatic to gene *B* makes the consideration of the three small-egg classes of vital concern in breeding operations. It is this group of birds that indicates the blending effect reported in crossing large-egg and small-egg breeds. This blending of intermediate effect also is to be expected in progeny from mating large-egg hens to males carrying gene *A* within the same flock, thus:

Typical Matings

♂ *F*102 (*AaBb*) X ♀ *E*319 (*AABb*) gave 13 daughters, all small; expected 13 daughters, all small.

Small egg phenotypes gave 7:4:2, expected 5:6:2.

♂ *G*980 (*aaBb*) X ♀ *F*2238 (*AaBB*) gave 5 small-egg to 6 large-egg daughters; expected 5½ small-egg to 5½ large-egg daughters.

Small-egg phenotypes gave 0:2:3; expected 0:2½:2½.

SUMMARY OF MATINGS

♂ *F*102 (*AaBb*) X 4 dams gave 34 small to 7 large; expected 32.6 small to 8.4 large.

♂ *F*1372 (*AaBb*) X 3 dams gave 31 small to 3 large; expected 29.7 small to 4.3 large.

♂ *G*148 (*AaBb*) X 3 dams gave 32 small to 11 large; expected 36.5 small to 6.5 large.

♂ *G*980 (*aaBb*) X 5 dams gave 21 small to 42 large; expected 17.8 small to 45.2 large.

♂ *G*1440 (*aaBb*) X 3 dams gave 34 small to 9 large; expected 32.8 small to 10.2 large.

All of these ratios are reasonably close to expectation for a small population. To develop a flock that will breed true for large-egg size it therefore becomes necessary to make the flock homozygous for gene *B*, using only female breeders laying 56.7 g. or larger eggs and mating these to males that breed true for the large-egg gene.

Large-egg size alone is apparently a simple characteristic to breed for, yet possible linkage relations of genes *A* and *B* with desirable genes from the standpoint of high fecundity may be such as to complicate a breeding program where maximum egg production and large-egg size are both desired. Future work may disclose linkage between factor *A* for small eggs and factors *E* or *E′* for early sexual maturity or possibly with genes *I* or *I′* for high intensity.

Egg Shape.—Still less has been accomplished concerning the inheritance of egg shape. Benjamin (1920) found that egg shape is inherited, long, narrow eggs apparently being dominant to short, round ones, whereas Kopéc (1924) observed the reverse but neither investigator made any determinations of the number of genes involved.

Shell Color.—The matter of shell color is of particular importance in "white-egg" breeds, such as Leghorns and Anconas, because many strains of these breeds frequently produce tinted eggs which discount the market value of the rest of the eggs. Hurst (1905) crossed Black Hamburgs, which lay a white egg, with Buff Cochins, which lay a brown egg, and found that the progeny produced eggs of an intermediate tint. Punnett and Bailey (1920) investigated the matter further and concluded that the color of the brown egg is due to several genes. Undoubtedly the safest plan for the practical breeder of white-egg breeds to follow is to eliminate hens that lay tinted eggs.

CHAPTER X

BREEDING PRACTICE

The discussion in the previous chapter concerning the inheritance of egg production has a very practical bearing on breeding practice inasmuch as the major receipts from all poultry products are obtained from eggs. This is true for all sections of the country as the following figures show. According to Jull et al. (1924), in California in 1922 eggs contributed 89.05 per cent and in Missouri in 1923 they contributed 70.80 per cent of the total receipts from poultry products. According to Misner, Johnson and Marble (1927*a*, 1927*b*), in the case of 32 commercial poultry flocks on Long Island and in the case of 121 farm flocks in New York State, not on Long Island, eggs contributed 68.30 and 55.00 per cent, respectively, of the total poultry receipts.

Breeding practice based on the principles of the inheritance of egg production, therefore, is of great practical significance to poultrymen. At the same time, it should be emphasized that the question of breeding the most suitable type of bird for meat production should not be neglected. The production of poultry meat and eggs should be combined to provide the greatest profits in poultry raising. Since egg production is so relatively important, however, it is well to consider certain practical factors that determine largely the revenue to be made from eggs.

Heavy Spring Production.—According to the best information available, the average egg production for all birds of laying age in the United States is estimated to be about 80 eggs per year. It is furthermore estimated (Titman 1928) that approximately 60,000,000 cases of 30 doz. eggs each were produced in the United States in the four months of March, April, May and June, 1927. Since there were approximately 400,000,000 hens of laying age on the farms of the United States on Jan. 1, 1927, if they laid an average of 80 eggs per bird, the total production would amount to approximately 89,000,000 cases. The number of eggs produced in the four months of March, April, May and June approximates 65 per cent of the total production for the year. Figure 35 shows in graphic form the proportion of eggs received by five of the country's largest market centers, New York, Chicago, Philadelphia, Boston and San Francisco, for each month for the years 1921, 1922 and 1923. It will be seen that by far the heaviest receipts are during the months of March, April, May and June.

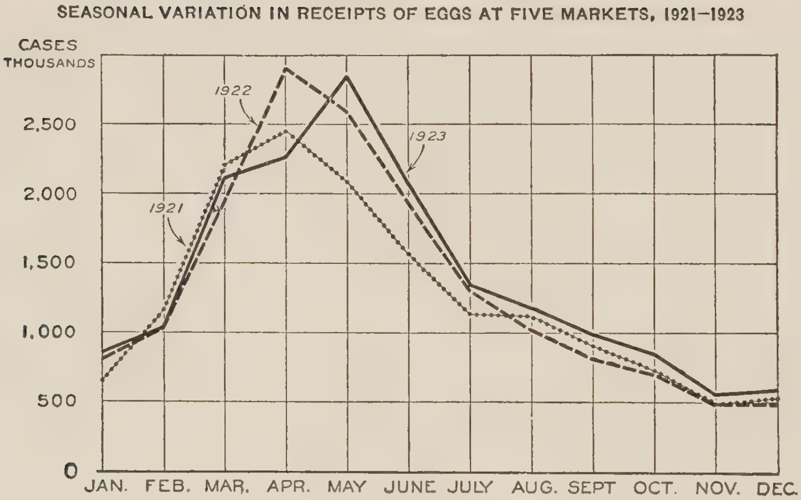

Fig. 35.—The seasonal variation in receipts of eggs on the five markets reflects accurately the seasonal variation in production. They are heaviest during the spring months, gradually decline during the summer and fall, and reach their lowest point in November or December. From this point they increase again rapidly until they reach their highest point in April or May. (*U. S. Dept. Agri.*)

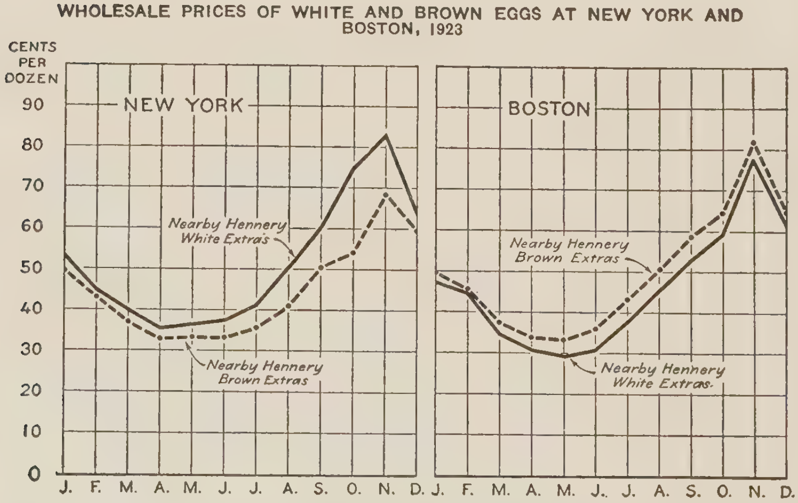

Fig. 36.—The New York market shows a price preference which is nearly uniform throughout the year for white eggs as compared with brown, whereas the reverse is true in Boston. The shell color of eggs, although having no effect on their food value or quality, is, therefore, a factor to be considered in selecting the market to which shipment should be made. (*U. S. Dept. Agr.*)

Importance of Fall and Early Winter Production.—The correct basis for determining the worth of any hen as a layer should be not only the total number of eggs produced but also the time of production. Ten eggs laid in November or December are worth approximately 20 laid in April or May. The average farm hen lays principally from March to June, the season of lowest prices, and, consequently, the season of relatively lower profits than at others times of the year. A study of the trend in the average monthly farm prices from 1910 to 1924 shows that lowest wholesale egg prices prevail in April, and that there is a slight increase in July and August, with a more perceptible increase beginning in September. The highest price is reached in December, which is also the season of highest profits, provided there is good egg production. If there is good egg production during the fall and winter, moreover, the average price per dozen for the year is increased. The trend of wholesale prices is illustrated in Fig. 36.

Factors Affecting Economic Returns.—In actual practice there are four primary factors which affect economic returns in the production of eggs for market. These four factors are: (1) The quantity of feed consumed, (2) the price of feed from time to time, (3) the number of eggs produced, (4) the prevailing price of eggs at the time of production. The poultry man has little or no control over the price of feed or the price of eggs. Under ordinary conditions of practice the average quantity of feed consumed per bird from month to month is fairly stable. The poultry man can control the rate of egg production at different times of the year, and it is this particular aspect that deserves special mention. There is some variation in feed prices from season to season throughout the year but not nearly to the same extent as pertains to egg prices.

Relative Value of Monthly Production.—The significance of the value of monthly egg production in relation to the monthly price of eggs is clearly shown in Figs. 35 and 36 and in the data given in Table 28. In this table a comparison is shown between the percentage of monthly production and the percentage of monthly "returns." In the case of 36 New Jersey commercial flocks the returns are in terms of the average cash receipts per flock, and in the case of 400 Missouri farm flocks the returns are in terms of profits over feed per bird.

It will be seen that in the months of September, October, November, December, and January, in the case of both New Jersey and Missouri, the percentage of returns is greater than the percentage of production, which is not true of the other months of the year. This simply means that eggs are worth more relatively during the five months mentioned, and, consequently, production during this period has a relatively higher value than at other times of the year.

Increasing Fall and Early Winter Production.—The relative value of fall production during the pullet year has been clearly demonstrated

Table 28.—Relation of Percentage of Monthly Egg Production to Percentage of Monthly Receipts per Flock in 36 New Jersey Commercial Flocks, 1916, and the Relation of Percentage of Monthly Production per Bird to Percentage of Monthly Profits over Feed per Bird in 400 Missouri Farm Flocks, 1923
(U. S. Dept. Agr. "Yearbook," Separate 917, 1924)

Month	New Jersey		Missouri	
	Production per flock, per cent	Receipts per flock, per cent	Production per bird, per cent	Profit over feed per bird, per cent
November	3.20	5.50	3.26	4.75
December	4.30	7.10	3.82	5.04
January	6.50	7.70	6.52	6.98
February	8.50	7.80	7.24	7.07
March	12.80	10.00	12.81	10.37
April	14.10	10.40	12.17	10.16
May	13.70	10.30	13.28	10.99
June	11.30	9.40	10.42	8.02
July	9.70	9.70	9.15	6.82
August	9.10	7.60	8.03	7.77
September	4.90	6.90	7.48	12.19
October	3.10	5.40	5.89	9.71

Table 29.—Five Years' Averages in Egg Production by Months From the Connecticut Home Egg-laying Contest Records (Jones, 1925)

Month	Standard production	1919 to 1920	1920 to 1921	1921 to 1922	1922 to 1923	1923 to 1924
November	5	3.70	3.91	4.95	5.45	5.49
December	7	5.30	6.75	7.40	7.43	8.71
January	9	7.70	8.46	9.26	9.25	9.18
February	12	9.40	11.16	11.04	10.59	10.96
March	18	15.60	16.43	16.30	15.65	15.55
April	19	16.70	17.66	17.44	16.87	16.63
May	20	16.70	17.45	17.49	17.26	17.00
June	18	14.40	14.71	15.13	14.33	15.30
July	17	13.30	14.37	14.53	14.38	14.50
August	15	12.30	13.29	13.95	13.75	13.34
September	13	10 00	10.98	10.90	11.02	10.11
October	7	6 40	7.30	6.66	7.08	6.40
Average for each year	160	131 45	147.67	144.82	143.11	141.65
Average number birds		26,361	29,036	55,131	64,053	88,297
Number of flocks		166	194	282	252	350
Average number birds per flock		159	149	192	254	252

by Kennard (1921), Jull (1923*a*, 1923*b*), Kempster (1926*a*), Jones (1925) and Buster (1927). Data submitted by Jones are particularly interesting in demonstrating the possibility of increasing production during the fall months. Table 29 shows the average egg production per bird per month over a period of five years, the interesting point being that the production for November and December increased consistently in spite of the fact the number of flocks and the average number of birds per flock were greater during the last three years.

It is clearly evident from the preceding discussion that there is much room for improvement in the average egg production of the birds of the country as a whole. The greatest improvement needed is in respect to fall and winter laying during the commencement of the pullet-year production and also in respect to late summer and fall production during the end of the pullet-year production.

Steps to Follow.—Breeding practice to increase egg production should take into consideration the constitutional vigor of both males and females, earliness of maturity in the pullets, intensity of production, non-broodiness and persistency of production, all of which have been discussed in the previous chapter.

It was also pointed out in the previous chapter that the proper selection of the breeding stock is the keynote in any improvement plan. Regardless of whether trap nesting is being practiced, considerable progress in the development of a high laying strain can be made by selecting breeders based on their performance, but if trap nesting is practiced then the progeny test should also be applied. Then, again, breed type and standard-bred quality should be given consideration, especially if hatching eggs, baby chicks or breeders are to be sold.

Select for Standard Quality.—In the breeding of standard-bred poultry reasonable care must be taken to maintain standard-bred qualities, particularly breed type and plumage coloration as well as freedom from disqualifications, such as side sprigs, stubs on the shanks of breeds with non-feathered shanks, squirrel tails and wry tails. Bittenbender (1922) discussed the possibility of combining breed type and other standard-bred qualities with egg production in Rhode Island Reds. Such is a possibility in the case of practically all popular breeds and varieties although it is apparent that the greater the number of desirable characters being bred for the more complex becomes the breeding program. As in the breeding of other classes of live stock, proper consideration must be given to breed standards. As many factors as possible should be taken into consideration when selecting both male and female breeders, for proper selection is the keynote to further progress.

Select for Vigor.—That constitutional vigor is of paramount importance in laying stock is evidenced by the fact that a 4-lb. Leghorn and a 6-lb. Rhode Island Red laying 216 eggs of standard size, 2 oz. each, would produce a weight in eggs equivalent to six times the weight of the Leghorn and four times the weight of the Rhode Island Red. High egg production constitutes a heavy drain on the birds' digestive and reproductive systems. A female must possess abundance of constitutional vigor to stand the strain of continuous production. Since constitutional vigor is inherited, the males should also possess it in abundance in order to transmit it to their progeny.

Select Good Body Type.—Good width of head, a stout beak, and a pair of prominently developed, bright eyes are characteristics of vigor. Good width, fair length and good depth of body are desirable, realizing, of course, that depth of body in different breeds is a relative matter, some breeds having greater depth than others. The keel should be of good length to give proper support to the abdominal muscles. The legs should be placed well apart, knock-knees being particularly objectionable since they are an indication of constitutional weakness. While ruggedness is desirable in both male and female breeders, extremely coarse birds should not be selected as breeders. Breeders should possess "quality," using that term in a very general sense to denote refinement in the different body characters and applied particularly to a thin, pliable skin and smooth scales on the shanks.

Select for Factors Affecting Production.—The selection of breeders based on their performance is a matter of easy application whether one is trap nesting or not. Where trap nesting is practiced it is an easy matter to determine and record the pullets that commence laying early in life, those that have a high intensity of production, those that do not go broody or exhibit very little broodiness, those that show no winter pause in production, and those that lay well during the summer and fall months before terminating the first-year production.

Select for Early Maturity.—Where trap nesting is not practiced the matter of selecting the best annual layers for future breeding purposes is not quite so simple but is still easily done. In the fall of the year as the pullets commence laying they should be banded with a numbered aluminum or colored celluloid band. A very easy way of determining the approximate time that pullets commence to lay is by noting carefully the development of the comb and wattles and the width between the pubic bones.

From practical experience it has been found that birds of the lighter breeds, such as Anconas and Leghorns, should commence laying at about 180 days of age and birds of the heavier breeds such as Plymouth Rocks and Wyandottes should commence laying at about 200 days of age.

Select For Intensity.—Pullets that lay at a high rate can be detected by the degree of bleaching of the yellow pigment, in normally yellow-pigmented breeds, such as Leghorns and Plymouth Rocks. The physiological relationship between depigmentation and egg production is discussed on page 79. During January or February the layers should be examined and those with the whitest beaks and shanks should be banded with a numbered aluminum or colored celluloid band.

Select for Non-broodiness.—The banding of birds according to the number of times they go broody should be a very simple matter.

Select for Persistency.—Persistent layers during the summer and fall months could be banded quite readily.

Practice System of Banding.—Such a system of banding is entirely practical and should do a great deal to improve the laying qualities of the flock if practiced from year to year. The banding of the birds should follow a definite method so that at the end of the year the best layers may be identified at a glance. If numbered aluminum bands are used the numbers could be recorded under the four headings—earliness of maturity, intensity of production, broodiness and persistency of production. Numbers recorded under the first two and the last headings indicate desirable birds, while numbers recorded under broodiness would indicate undesirable birds.

If colored celluloid bands are used, one color, such as red, should be placed on the left leg of each bird to denote earliness of maturity; another color, such as white, should be placed on the right leg of each bird to denote intensity of production; a black band should be used every time a hen goes broody; and a blue band should be used to identify the persistent layers. Red for an early start, white for bleaching after intensive laying, black in mourning for broodiness, and blue for persistency. At the end of the year the best layers would each have a red, a white and a blue band.

Practice Progeny Testing.—But the real value of the measure of an animal as a breeder is the kind of progeny it produces. What the poultry breeder desires above all else is a method of selecting male and female breeders that can be relied upon with a considerable degree of assurance to bring about an increase in egg production. This is desired particularly in the case of males, since the offspring of each male are much more numerous than the offspring of any female and the male constitutes one-half of the heritage given to all of the offspring.

In this connection, the results of an exhaustive study of dairy cattle breeding are especially illuminating and may have considerable significance to poultry breeders in the selection of their breeding stock. Pearl (1920) determined the transmitting ability in respect to milk production of every Jersey bull recorded in the Jersey Registry of Merit up to 1916 as having two or more daughters whose milk-producing qualities were known, as well as the milk-producing abilities of the dam. In his discussion of the situation, a very interesting table is presented showing each bull with his pairs of daughter-dam tests, and the number of pounds of butter fat that his daughters are in excess or defect of their dams. Of the 224 bulls shown in the table a very real picture is presented concerning their actual merits and demerits as breeders. Many of the commonly recognized leading bulls of the breed are shown to have had a very detrimental effect and Pearl concludes "that the appearance of certain famous animals in the pedigree of a given bull is no guarantee of that particular bull's worth."

Gowen (1924*b*) in a similar study of transmitting ability in the Holstein-Friesian breed concludes that for predicting the probable milk yield of a given animal, the combination which has been found to be of the greatest value are records of a full sister and of the dam, and the next most important combination is the records of a half sister by the same sire and of the dam. A knowledge of the ancestry of an animal will often disclose whether it is homozygous or heterozygous for a particular character. And a study of ancestry should include not only the dam, sire and grandparents but full sisters and half sisters as well. In addition to this, a study of the progeny will reveal information of great value.

The facts established in connection with the dairy breeding industry will undoubtedly prove of the greatest possible value when applied to the poultry breeding industry. Think of one item alone, the selection of male breeders based upon the performance of full and half sisters and dams. Such a method of selection is particularly appropriate in breeding for increased egg production inasmuch as earliness of sexual maturity, intensity, and persistency of production are correlated with annual egg production thereby providing an excellent basis for the selection of breeders based on the performance of full and half sisters, dams and, more important still, the progeny.

Hagedoorn (1926) describes a very useful and practical method of applying the progeny test in the case of males. He suggests making up breeding pens, each composed of full and half sisters of birds in all other pens. All pens, therefore, are composed of females of the same breeding and the results their daughters give in egg production give a very good test of the breeding value of the males.

Select for Hatchability and Livability.—The selection of breeders based on the progeny test should also take into consideration the results secured in respect to hatchability of the eggs and the livability of the chicks. A male might be selected as a breeder because he was out of a high-producing dam and because 5 full sisters and 21 half sisters were good producers, but he might prove to be a poor breeder because he carried genes for low hatchability.

The selection of breeding stock may be carried out with the utmost care, but little progress might be made, however, in building up a heavy laying strain because of the adoption of poor systems of breeding or improper methods of mating.

SYSTEMS OF BREEDING

A system of breeding is understood to mean the breeding of birds according to a definite plan or policy, usually over a period of years, with a specific objective in mind. The breeding of brothers and sisters might be practiced for a number of years for the purpose of determining the effects of such close inbreeding on such characters as hatchability, egg production, and constitutional vigor. Breeds might be crossed for the purpose of determining the inheritance of plumage color and other characters, such as fleshing properties. Mongrel females might be mated to pure bred males year after year for the purpose of improving the general qualities of the flock. Thus there are three rather definitely established systems of breeding: inbreeding, including line breeding; outbreeding; grading.

Inbreeding.—Inbreeding is the mating together of relatives, and since there are degrees of relationship, such as full brothers and sisters, aunts and nephews, uncles and nieces, first cousins, and tenth cousins, so there are degrees of inbreeding. There is what is called "close inbreeding," as in the case of full brother and sister mating or there may be inbreeding of tenth cousins, which certainly could not be regarded as close inbreeding. Line breeding is a form of inbreeding; close inbreeding is avoided but the desirable qualities of the inbred stock are maintained through the adoption of a definite system over a period of years.

According to Crew (1925*c*), "the records of the breeds of domestic animals show that close inbreeding or line breeding of good stock, if associated with the usual elimination of the weakly, may be practiced for many generations without any undesirable consequences." There are two very important qualifications in the preceding statement that deserve emphasis before further discussing inbreeding. The two qualifications are: *good stock* and *the usual elimination of the weakly.* Unless good stock is started with, the results in inbreeding poultry are apt to be very disastrous. Crew's statement presupposes the appearance of weakly individuals, which is in keeping with observed results in many cases of inbreeding in poultry. Unless rigid selection from year to year is insisted upon, based upon the amount of constitutional vigor possessed by the individuals, the inbred lines are likely to show decrease in vigor.

Purpose of Inbreeding.—Many poultry breeders believe thoroughly in inbreeding or are definitely opposed to it without understanding its real purpose. In ordinary practice the real purpose of inbreeding is to intensify desirable qualities. To express the same idea in another way, the real purpose of inbreeding is to develop birds whose genes are in a homozygous condition for as many desirable characters as possible. In the development of a bred-to-lay strain it is desirable to have all the females possess the genes for earliness of maturity, intensity of production, non-broodiness and persistency of production. One bird may possess the genes in a heterozygous condition for the first two characters and another bird may possess the genes also in a heterozygous condition for the last two characters. By mating the progeny of the two birds and then practicing inbreeding it should be possible to develop birds possessing the genes in a homozygous condition for all four characters. As a matter of fact, inbreeding has been practiced to some extent in nearly all flocks where high egg-production has been developed and maintained. Inbreeding was practiced rather extensively in the development of some of the more outstanding strains of horses, cattle, sheep, and swine.

Effects of Inbreeding.—Inbreeding if practiced properly is not necessarily harmful, and in fact is often very advantageous. Great caution must be exercised, however, in the selection of breeders, otherwise very harmful results will follow. It must be realized, for instance, that genes for bad characters may be transmitted from generation to generation along with genes for good characters. Inbreeding intensifies undesirable characters as well as desirable ones and rigid selection must be employed to prevent degeneration. What the great majority of poultry breeders do not realize is that different results in inbreeding are to be expected when different kinds of stock are used at the beginning.

Comparatively little experimental work with poultry has been conducted to determine the effects of inbreeding. The results of four lines of work are available, however, and they are discussed very briefly for the purpose of presenting some of the more important problems that must be kept in mind when inbreeding poultry.

Inbreeding Effects on Hatchability.—Cole and Halpin (1916, 1922) inbred Rhode Island Red brothers and sisters for four years and observed a marked decline in vigor to such an extent that in the fourth year hatchability was so low that the experiment had to be discontinued. The basis of selecting the full sisters and brothers each year was on the color of the plumage of the birds, other characters, such as constitutional vigor and egg production, not being considered. Another inbreeding experiment was started with Rhode Island Reds in which full brothers and sisters were selected each year based on the hatchability of the eggs and the livability of the chicks, these two characters having been assumed to be a measure of constitutional vigor of the parent stock. The results of the second experiment are not available, although it is stated (1922) that the general vitality of the stock was raised but egg production decreased, which may have been due to the fact that egg production was not taken into consideration in selecting the breeders each year. The hatchability results are shown in Table 30.

Dunn (1923*c*) reports the results secured in inbreeding six lines of White Leghorns in which case the basis of selection each year was the number of full sisters available for mating on February first of the pullet year. At that time the group was chosen which had the largest number of full sisters and at least two full brothers, one for mating and one for reserve. The general results observed after three years of brother-sister mating were: marked decrease in hatchability each succeeding year as shown in Table 30; somewhat increased chick mortality up to three weeks of age, increased adult mortality, a decline in the growth rate, later sexual maturity of the pullets and a decline in winter and annual egg production.

TABLE 30.—PER CENT HATCHABILITY AS AFFECTED BY CONTINUOUS BROTHER AND SISTER MATING

(Cole and Halpin and Dunn)

Authority	Breed	Mating	First year	Second year	Third year	Fourth year
Cole and Halpin......	R. I. Reds	Inbred line	67.0	49.0	41.0	18.0
		Control line	67.0	31.0	56.0	64.0
Dunn...............	White Leghorns	Inbred line	76.8	49.2	42.0	21.7
		Control line	51.6	49.8	64.6	60.8

Hays (1923) gives the results of inbreeding, not entirely brother-sister mating, in Rhode Island Reds and observes that sexual maturity was retarded and winter egg production apparently declined.

Goodale (1927) in six generations of brother-sister mating in one line of White Leghorns, found that the average egg production decreased from 224 in the first generation to 113 in the second generation and thereafter remained relatively constant, and he believes that there is "every prospect that lines of poultry genetically pure for egg production characters will eventually become established."

Jull (1929*c*) gives the results secured in hatchability in three years of full brother and sister mating and half brother and sister mating in Barred Plymouth Rocks and Single-comb White Leghorns. That hatchability decreased as such close inbreeding was continued is evident from the data given in Table 31.

The results cited above all show the general effects of close inbreeding in poultry and suggest the inadvisability of continued brother-sister mating except for the specific purpose of establishing the homozygosity of certain genes. Practical breeders seldom mate full brothers and sisters though sometimes half brothers and sisters are mated as well as sons being mated back to their dams and sires being mated to their daughters.

Line breeding, where one bird is mated to its progeny for two or three years in succession, is sometimes practiced. Less close inbreeding is practiced quite frequently and has proved to be very valuable in developing bred-to-lay strains as well as standard-bred birds of high quality.

TABLE 31.—HATCHABILITY RESULTS IN BARRED PLYMOUTH ROCK AND SINGLE-COMB WHITE LEGHORN MATINGS VARYING IN RESPECT TO THE CONSANGUINITY OF THE BREEDING STOCK

Barred Plymouth Rocks

Mating numbers	Kind of mating	No. of hens	Per cent embryo mortality 1–17 days	Per cent embryo mortality 18–21 days	Per cent chicks hatched
1 (Group I)....	Outbred	18	6.47	21.10	72.42
2 (Group II)...	Inbred 1st year	20	21.96	39.42	38.62
3 (Group III)..	Outbred	10	13.28	33.61	53.11
4 (Group V)....	Inbred 1st year	16	8.88	39.35	51.78
5 (Group I)....	Outbred	20	9.00	14.80	76.20
6 (Group II)...	Inbred 1st year	23	11.62	45.76	42.62
7 (Group IV...	Inbred 2d year	22	10.58	45.00	44.42
8 (Group VI)...	Inbred 3d year	11	15.83	61.00	23.17
Group I.......	Inbred Outbred	38	7.85 ± 0.666	17.67 ± 1.150	74.48 ± 1.293
Group II......	Inbred 1st year	43	15.87 ± 1.372	43.15 ± 2.123	40.98 ± 2.016

Single-comb White Leghorns

Group numbers	Kind of mating	No. of hens	Per cent embryo mortality 1–17 days	Per cent embryo mortality 18–21 days	Per cent chicks hatched
IX	Outbred	37	4.46 ± 0.467	13.00 ± 1.042	82.54 ± 1.140
X	Inbred 1st year	44	9.65 ± 0.902	28.97 ± 1.897	61.48 ± 1.842
XI	Inbred 2d year	44	12.32 ± 0.930	35.82 ± 2.024	51.86 ± 1.858
XII	Inbred 3d year	36	12.47 ± 1.433	38.94 ± 1.786	48.59 ± 1.936
XIII	Inbred Outbred	124	10.00 ± 0.556	20.91 ± 0.893	69.10 ± .0956

Rigid Selection Necessary.—It has become apparent that whenever inbreeding is practiced the breeding stock must be selected most rigidly on the basis of constitutional vigor, as judged not only by external appearances but also by the results of the progeny test. The breeding worth of a bird is determined by the kind of progeny it produces rather than by its physical appearance. The application of the progeny test is particularly important when inbreeding is practiced because a decrease in vigor is apparently revealed in decreased hatchability of the eggs, increased mortality in the chicks, and later sexual maturity. Inbreeding to some extent is most advisable in order to *fix* desirable characters in a strain but rigid selection of the breeding stock is doubly imperative since the greater the amount of inbreeding the greater the degree of homozygosity of undesirable genes that accompany desirable genes.

Outbreeding.—The term "outbreeding" is used in contradistinction to "inbreeding"; in the former there are practically no common ancestors, whereas in the latter there are two or more common ancestors, depending upon the amount of inbreeding; the closer the amount of inbreeding the more common ancestors there are. Practical poultry breeders think of outbreeding as implying the crossing of breeds such as Leghorns and Jersey Black Giants. The term actually has a more general application, however, since it covers those cases in which the birds mated differ in characters the inheritance of which are being studied. The crossing of Single-comb White Leghorns with Single-comb Black Leghorns is an instance of outbreeding for the purpose of determining the inheritance of white and black. Genes for white are outbred with genes for black. Outbreeding also includes such crosses as Single-comb with Rose-comb White Leghorns, in which case genes for single comb are outbred with genes for rose comb for the purpose of determining the manner in which the two kinds of genes are transmitted from generation to generation.

While inbreeding constitutes the mating of related individuals, outbreeding naturally involves the mating of unrelated individuals, the particular point to be kept in mind is that it is the genes that are related in the one case and unrelated in the other case. Since the manner in which the genes are transmitted from generation to generation constitutes the basis of inheritance studies, the nature of the genes being mated determines whether inbreeding or outbreeding is being practiced.

In practical breeding work, however, outbreeding is understood to mean the crossing of breeds, and the term "outbreeding," therefore, is synonymous with cross-breeding. The most outstanding advantage gained in outbreeding is in respect to the constitutional vigor of the progeny. In the F_1 generation the effects of inbreeding may not be very noticeable but in outbreeding they are usually quite noticeable.

Purpose of Outbreeding.—The real purpose of outbreeding, however, is not only to develop greater vigor in the progeny but also to provide for the combination of desirable qualities from two distinct lines of stock. At the same time, very little is to be gained by crossing animals that have not been carefully selected. Jones (1925) points out that "Uniform progeny are produced only when the parental races are fixed in their particular type and breed true, and it is only when they are from separate and different lines of descent that decidedly beneficial results from crossing can be expected." In this connection it is very interesting to note that many grand champion steers, wethers and barrows at national and international live-stock shows are cross-bred animals, produced from parents of superior quality.

Outbreeding Effects on Hatchability.—The gain in constitutional vigor as a result of outbreeding has been demonstrated many times both in plant and animal breeding work. Pearl and Surface (1910*c*) crossed Barred Plymouth Rocks with Cornish and observed an increase in hatchability over that of each breed, as shown in Table 32. Warren (1927) crossed White Leghorns with Jersey Black Giants and also observed an increase in hatchability over that of either parental breed, as shown in Table 32. Warren also notes in his White Leghorn-Jersey Black Giant mating that chick mortality in the F_1 chicks was 3.2 per cent as compared with 12.2 in White Leghorn chicks and 19.9 in Jersey Black Giant chicks, and first-year egg production in the F_1 pullets averaged 212.9 eggs per bird as compared with 173.8 in White Leghorn pullets and 162.3 in Jersey Black Giant pullets.

TABLE 32.—PER CENT HATCHABILITY AS AFFECTED BY OUTBREEDING
(Pearl and Surface and Warren)

Authority	Mating	Per cent hatchability
Pearl and Surface. .	B. P. Rock × B. P. Rock	47.67
	Cornish × Cornish	55.00
	B. P. Rock ♀ × Cornish ♂	66.00
	Cornish ♀ × B. P. Rock ♂	73.00
Warren.	J. B. Giant × J. B. Giant	57.2
	White Leghorn × White Leghorn	73.2
	White Leghorn × J. B. Giant	77.8

Outbreeding Increases Vigor.—The reasons for increased vigor as the result of outbreeding are not clearly understood although at least one plausible explanation has been offered. It has already been seen that the effects of inbreeding have been interpreted in terms of the homozygous condition of genes for desirable and undesirable characters, homozygosity of the genes for desirable characters constituting the advantages of inbreeding and homozygosity of the genes for undesirable characters constituting the disadvantages of inbreeding. The effects of outbreeding, on the other hand, are interpreted in terms of the heterozygous condition of genes for desirable characters introduced from each of the lines crossed.

The situation is further discussed by Crew (1925*c*), who uses the term "heterosis" to mean hybrid vigor.

Mendelian analysis suggests very strongly that the characters—morphological and physiological—result from the action of the genes residing on the chromosomes and that in the production of each character more than one gene is concerned. No one individual possesses all the favorable characters, each is a random sample of good and bad. Usually normality is dominant over abnormality. This being so, the F_1 individuals must contain the maximum number of different genes. Heterosis is related to heterozygosis.

The most plausible explanation of hybrid vigor or heterosis resulting from outbreeding is offered by East and Jones (1919). One of the parents possesses dominant genes in a homozygous condition which produce a certain amount of vigor while the other parent possesses another group of dominant genes in a homozygous condition which produce the same amount of vigor as in the other parent. Each parent, of course, carries the recessive genes of the dominant ones carried by the other parent. When the two parents are crossed, the F_1 birds carry a dominant gene from each of the parents and, therefore, have twice as many dominant genes as each of the parents. The dominant genes, however, are each in a heterozygous condition and East and Jones assume that they are as effective in producing vigor when in a heterozygous condition as when in a homozygous condition. Whether this is a complete explanation of the phenomenon of hybrid vigor arising from outcrossing is uncertain at this time although it is the best explanation offered so far.

Outbreeding in Practice.—Outbreeding is practiced by poultry producers for the production of broilers and roasters. For broiler production crosses are frequently made between Plymouth Rocks and Wyandottes, Leghorns and Wyandottes, as well as other breeds. The production of roasters often involves such crosses as White Plymouth Rocks and Light Brahmas, a cross practiced for years in the South Shore district of Massachusetts for the production of roasters for the Boston market. Whether outbreeding for egg production purposes should be encouraged seems quite doubtful at the present time. It is apparent, of course, that the most distinct advantages of outbreeding occur only in the first cross and the two original breeds must be maintained for the purpose of making subsequent crossings.

Grading.—The term "grading" is used to denote the mating of common or mongrel stock to birds of superior quality for the purpose of improving the qualities of the mongrel stock. Grading nearly always involves the use of pure-bred males of high quality on mongrel females. The practice is justified because of the benefits usually resulting therefrom and because of the relatively low cost involved. Lippincott (1920) demonstrated the economic value of grading in the case of mongrel hens mated in each case to Single-comb White Leghorn and Barred Plymouth Rock males. The average annual egg production of the pullets hatched each year increased quite materially up to and including the third generation.

Lippincott's results demonstrate quite clearly the possibility of thousands of the flocks of the country being improved through the use of well-bred males. On the other hand, the recent development of the commercial hatchery business in the United States, making it a fairly simple problem to replace the entire flock of mongrels with chicks from bred-to-lay flocks, detracts somewhat from a long-time grading program.

METHODS OF MATING

Whatever may be the system of breeding employed, it is obvious that the breeding stock must be given the best of care and proper methods of mating must be employed or the results in the reproduction of the flock from year to year will not be satisfactory.

The breeding stock used each year should not only give good results in respect to the fertility and hatchability of the eggs set and the livability of the chicks hatched, but also improvement should result in the quality of the stock produced each year. If progress is not achieved from year to year, then something is inherently wrong with the stock being bred from; or the selection of the breeding stock each year is not founded upon sound principles; or the system of breeding is at fault; or improper methods of mating are made; or any combination of these circumstances may prevail. It is most necessary, therefore, that the progressive breeder know the kind of stock he is dealing with and that he use intelligent methods in mating.

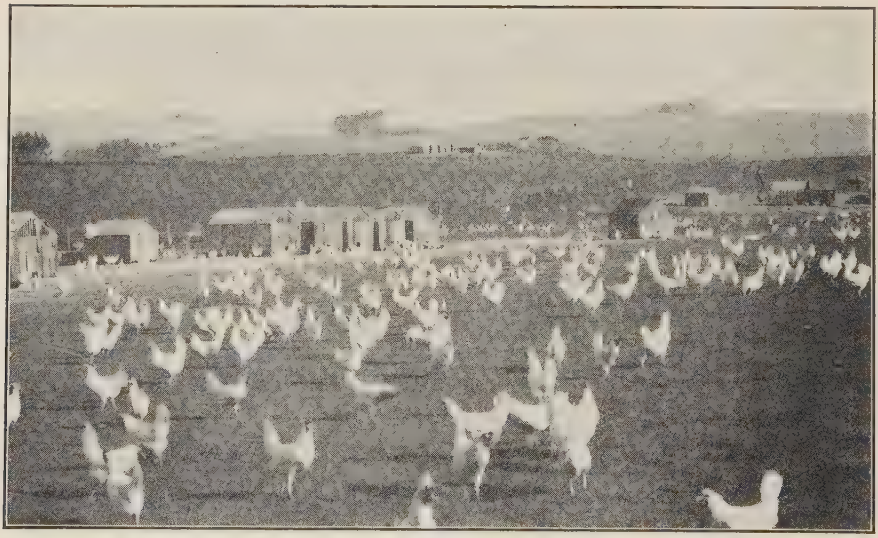

Fig. 37.—Free range on good soil for breeding stock used by a hatchery operator at Petaluma, Calif. (*Photograph by Must Hatch Incubator Co.*)

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There are two methods of mating that are practiced by the great majority of poultry breeders, mass mating and pen mating. Stud mating is practiced somewhat and artificial insemination is resorted to in particular cases.

Mass Mating.—Mass mating, or flock mating, simply means that a number of males are allowed to run with the entire flock of females. No pedigree breeding work can be carried on because the male parentage of the chicks would be unknown. Moreover, mass mating is practiced for the most part by commercial and farm poultry raisers. When all other conditions are satisfactory the percentage of fertile eggs is usually higher in mass matings than in any other method of mating. The number of males to use in a flock depends on the size of the flock and the breed. The approximate proportion should be about as follows: Brahmas and similar breeds, 1 male to 8 to 12 females; Plymouth Rocks and similar breeds, 1 male to 10 to 15 females; Leghorns and similar breeds, 1 male to 12 to 20 females. Best results in fertility can be obtained by keeping two sets of males, using each set on alternate days.

Pen Mating.—By the term "pen mating" is meant a pen of females mated to a single male. Those who practice pen mating usually undertake pedigree breeding work, in which case it is necessary to know the ancestry of every chick hatched. The number of females in the pen should be about the same as for one male in mass mating. Occasionally poultry breeders make up pen matings consisting of about 20 to 25 females mated to males that are full brothers. The pedigree of the chick can be given for all the ancestry except the male and this fea-

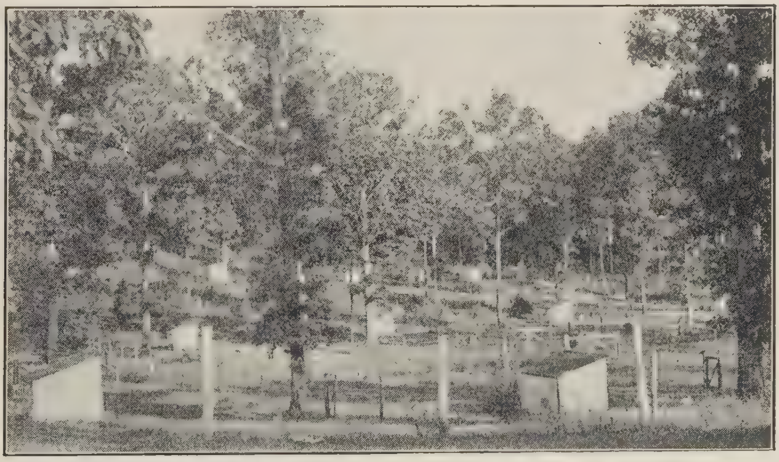

FIG. 38.—Breeding pens at the U. S. Animal Husbandry Experiment Farm, Beltsville, Md. Each breeding pen is housed in a colony breeding house which is located in the center of a yard 60 by 150 ft., thus providing the breeders with ample range on sanitary soil. (*Photograph by U. S. Dept. Agr.*)

ture often makes the practice of doubtful value because full brothers frequently give very different results when bred to the same females.

Stud Mating.—The term "stud mating" is used in those cases where females are mated individually with a male kept by himself in a coop or a pen. One advantage in stud mating is that the females to be mated to each male do not have to be kept in separate pens, such an arrangement making it unnecessary to build a colony house or provide a separate pen for each breeding flock. A certain amount of labor is also saved since a relatively large number of females may be kept in one flock.

Another advantage in stud mating is that more females can be mated with one male than in pen mating. Also, the time of mating can be distributed more evenly throughout the day, thus enhancing the male's reproductive ability. Philips (1918) observes that a White Leghorn male mated as many as thirty-eight times a day with White Leghorn females. Martin and Anderson (1918) report that of 34 White Leghorn females mated by a single male in one day, only 10 of the females laid fertile eggs. Craft, M'Elroy and Penquite (1926) show that males which are excessively active produce a larger percentage of dead and weak spermatozoa than males which mate less frequently. The ill effects of excessive sexual activity have been demonstrated in other classes of live stock and it is easily seen that stud mating, when properly employed, tends to conserve the reproductive ability of the male.

One important thing to be kept in mind when stud mating is practiced is that the males must be kept in good physical condition. A male kept confined in a small coop during the entire breeding season is apt to lead to the production of a high percentage of infertile eggs toward the latter part of the breeding season, apparently due to a lack of sufficient exercise. Barber (1927) has devised a unique stud-mating house which he uses with very good results. A house comprised of a number of small pens for each male to be used is built immediately in front of the laying house. Each male pen has a connecting doorway leading to the laying house, the doorway being large enough to pass a female from the laying house into the male pen. As the females are released from the trap nest they are each mated to the appropriate male, the proper mating numbers being located near the doorway. Each female is mated to her proper mate about every third day, which is sufficient to insure the fertility of practically all eggs laid, and in this way as many as 25 females of the larger breeds and 35 females of the smaller breeds can be mated to one male.

Artificial Insemination.—The practice of artificial insemination is sometimes resorted to in conducting special studies on the physiology of reproduction, in studying the inheritance of certain characters, and in making crosses between breeds differing widely in size. Ivanov (1914), Payne (1914), Amantea (1925), Dunn (1927*b*) and Maw (1928) have each described how artificial insemination is practiced. Briefly it may be said that the most practical methods are first to intercept the normal mating of a male and female with a small glass dish in which the sperm is collected and then, by means of a pipette, transfer the sperm to the female to be artificially mated and, second, to allow a normal mating to be made between a male and a female and then, before the mated hen is allowed to rise, remove with a pipette as much of the sperm as can be secured and transfer it to the cloaca of the female to be impregnated artificially.

FACTORS AFFECTING FERTILITY

In order that best results may be secured from any method of mating that may be employed, the poultry breeder should always keep in mind a number of factors that affect the number of progeny secured. One factor of considerable importance is the per cent of fertile eggs secured from the breeding flocks.

In breeding practice it is well to know how soon after a mating is made and how long after the mating is discontinued that eggs can be saved for incubation purposes. It is always well to test the fertility of males and females several weeks prior to the regular breeding season. Test the fertility of the eggs from each breeding pen at least one month in advance of the regular incubation period in order to be able to remate the birds if desirable.

Fertility upon Mating.—The first fertile egg laid after mating has been reported as follows: Gilbert (1905), 39 to 65 hr.; Pearl and Surface (1909*c*), 72 hr.; Coste and Gerk (1910), 28 hr.; Philips (1918*a*), 23 hr.; Erickson (1924), 72 hr.; Fronda (1926), 20 hr.; and Dunn (1927*b*), 21 hr. It should be noted that the observations of Coste and Gerk, Philips, Fronda and Dunn were based on individual matings whereas all other observations were based on pen matings. Anderson (1922) states that fertilization takes place mostly within 12 hr. after mating, although this could hardly apply to eggs laid 10 or 12 days after mating had taken place because the yolks of such eggs would not have reached the oviduct until approximately one day before being laid. Curtis and Lambert (1929) observed that the onset of fertile production ranged from 24 hr. to 7 days, with 57.1 hr. as the average.

Waite (1911*a*) from a flock of 20 White Leghorn pullets secured 50 per cent fertile eggs on the third day and 70 per cent fertile eggs on the fourth day after mating. Crew (1926) reports that maximum fertility is reached by the end of the first week after mating. From the practical standpoint, therefore, it may be stated that eggs may be saved for incubation beginning about the fifth day after the males have been placed with the females.

Fertility When Mating Discontinues.—The length of time that fertile eggs are produced after the mating pen has been discontinued is a matter of some practical importance, although usually the males are allowed to remain with the females as long as eggs are saved for incubation. Spallanzani (1784) reports that a hen can lay fertile eggs 20 days after being mated, while Crew (1926) secured a fertile egg 32 days after removal of the male, these observations being based on individual matings.

Of more practical importance to poultry breeders is the length of time that the fertility of eggs will remain sufficiently high in order that the eggs may be saved for incubation after the males have been removed from the breeding pens. The following observers report the approximate number of days that good fertility may be expected: Gilbert (1904, 1905), 11 days; Waite (1911*a*), 11 days; Chapellier (1914), 10 to 18 days; Kaupp (1915*a*), about 5 days; Elford (1916), 19 days; Philips (1918*a*), 15 days. Lillie (1919) observes that after the end of the third week the vitality of the spermatozoa is considerably reduced. Curtis and Lambert (1929) observed that the mean duration of fertility was about 11 days, with 21 days as the extreme duration. It would seem, therefore, that reasonably good fertility may be expected for about two weeks after the discontinuance of the breeding pen.

The question of cessation of fertility after mating is discontinued is of importance when it is desired to substitute males in the breeding pen and still have definite knowledge of the ancestry of the chicks hatched from both males. It has been observed previously that approximately three weeks after the male has been removed from the breeding pen practically no fertile eggs could be expected, for, although Crew secured one on the thirty-second day, it should be noted that its embryo did not develop beyond the second day of incubation. When males are substituted, therefore, fertile eggs secured after the third week after the removal of the first male may be regarded as having been fertilized exclusively by the second male. The influence of a previous mating is not permanent, despite a common belief to the contrary. The so-called influence of previous impregnations is called telegony but has no foundation in fact.

Preferential Mating.—It occasionally happens that certain females may not mate readily with a certain male but when mated with another male will mate with him quite readily. Preferential matings have been observed by Philips (1919*a*) and difficulties encountered in this respect can be overcome by moving the female from one pen to another, in which case, if pedigree breeding is being practiced, eggs should not be saved for incubation for at least three weeks, except as noted on the next page.

Selective Fertilization.—Selective fertilization has been demonstrated to take place, in which case it has been demonstrated that the spermatozoa of certain males fertilize the ovum more readily than spermatozoa from other males. The results of Crew (1926) and Dunn (1927*b*) demon-

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strate that there is competition among spermatozoa in fertilizing ova and that there may be physiological incompatibility between spermatozoa and ova as well as a relationship between the general vigor of the male and the fertilizing power of the spermatozoa it produces.

Warren and Kilpatrick (1929) mated two males alternately to different females and drew the following conclusions:

> If a male in a mating is replaced by another, the offspring of the replacing male very soon supplant those of the former and there is practically no overlapping of the offspring of the two males. The flagellum of the sperm is lost during the first day's existence in the oviduct of the female. This may account for the advantage which fresh sperm have over those which have been in the oviduct a longer period. In the case of timed matings, the later introduced sperm lose their advantage after they also have been in the oviduct for more than a day.

These results were secured under carefully controlled conditions and they demonstrate the fact that fresh spermatozoa compete successfully with spermatozoa introduced into the oviduct earlier. In pedigree breeding work, where different males are to be mated to the same females because of the death of one of the males, eggs for hatching could be saved from the second mating in about three or four days.

Fertility Not Inherited.—That fertility is not inherited has been demonstrated by Pearl and Surface (1909*c*) and by Hays and Sanborn (1924). From this it may be concluded that in order to secure maximum fertility the male and female breeders should be selected on the basis of physical vigor and the management of the breeding stock must be most efficient.

BREEDING VALUE AS INFLUENCED BY THE AGE OF THE BREEDERS

As compared with the larger classes of live stock, poultry are relatively short-lived creatures. The discussion in the latter part of the preceding chapter reveals the fact that egg production declines steadily each year with the advancing age of the female. In the case of males, practical experience has demonstrated that in the great majority of cases their reproductive value declines rather rapidly after the first year, due largely to the fact that as the male grows older his ability to produce a high percentage of fertile eggs declines. In other words, cockerels usually produce a higher percentage of fertile eggs than when they become yearlings, and thereafter they are relatively of little value. It should be noted, however, that males of the lighter breeds, such as Anconas and Leghorns, usually do not show as great a decline in breeding value as males of the heavier breeds, such as Jersey Black Giants, Light Brahmas, Plymouth Rocks, Rhode Island Reds and Wyandottes. At the same time, when the progeny test reveals that a particular male is a valuable breeder, he should be used as long as possible.

Stewart and Atwood (1909) report that two- and three-year-old White Leghorn hens gave better results than pullets in respect to percentage of eggs hatched, average size of chicks and percentage of chick mortality. Pearl (1917), with Barred Plymouth Rocks, observes that, in the case of both males and females, the reproductive capacity is greatest in the first breeding year as judged by the percentage of chicks alive at the end of the third week after hatching in proportion to the total number of eggs incubated during the breeding season. It should be noted, however, that during the breeding season the pullets laid better than the yearling hens and, moreover, there is no information as to any differences in the size of the chicks from the two groups of birds. Kempster (1921*a*), in the case of White Leghorns, reports that hens gave a 4 percent better hatchability of eggs set than pullets. On the other hand, Richardson (1924–1925) reports that 95 per cent of the commercial poultrymen in New Hampshire use pullets exclusively as breeders. Richardson observes that the pullets are hatched during the latter part of February and during March, that they are early maturing, and after having laid well until the latter part of October usually undergo a partial molt and largely cease production for a period of a few weeks. The rest period apparently enables the pullets to become satisfactory breeders, since the results in hatchability of eggs and the livability of the chicks are reported to be good.

Jull and Quinn (1925) and Upp (1928) show that there is a definite relationship between size of egg and size of chick and, since yearling hens usually lay larger eggs than pullets, chicks from yearling hens are nearly always larger than those from pullets. Finally, Hays (1928) observes from results secured with Rhode Island Reds that yearlings hens gave a slightly higher per cent of hatchability than pullets.

Taking all the evidence available into consideration, it seems fairly evident that yearling hens may be expected to produce somewhat better results in respect to hatchability and that the chicks at hatching time are usually larger than when pullets are used as breeders. If pullets are used as breeders, they should be hatched early and given a rest in the fall prior to the breeding season. Poultry breeders would be well advised to use as breeders those hens which prove to be good layers over a period of years since it is desirable to develop layers which not only lay well in their first year of production but also lay well during their second, third and fourth years.

MANAGEMENT OF THE BREEDING STOCK

The proper management of the breeding stock is of great importance in securing the largest possible number of good chicks in proportion to the eggs set.

The proper care of the male breeder is especially important, since he is the sire of every chick from each of the females in a pen. The male should get plenty to eat at all times during the breeding season. It is sometimes desirable to cut off the spurs of old males, otherwise the females are apt to be torn. In northern parts of the country the males are apt to have their combs and wattles badly frozen, to such an extent sometimes that they will not mate with the females. Payne and Ingram (1927) have shown, however, that a moderate amount of the freezing of the comb reduced fertility and hatchability only 11 days below normal. To avoid the danger of having combs badly frozen, some poultry breeders cut off the combs of males in the fall of the year, this practice being called "dubbing." It is also practiced occasionally in the case of two- and three year-old males, whose reproductive ability has apparently become reduced.

Unless the conditions under which the breeders are kept are almost ideal, both fertility and hatchability may be adversely affected. The breeders must be healthy and vigorous and must be kept in clean, well-ventilated houses. The houses should be kept free of mites and the birds free of lice. If the litter in the breeding house is allowed to become filthy, the fertility of the eggs may be lowered. The yards should be kept sweet and clean and should have a grass or other green crop growing on it, since good range is a very important factor in securing good hatchability and strong chicks. The houses should never be overcrowded, otherwise the fertility of the eggs will be materially affected.

CHAPTER XI

BREEDING RECORDS

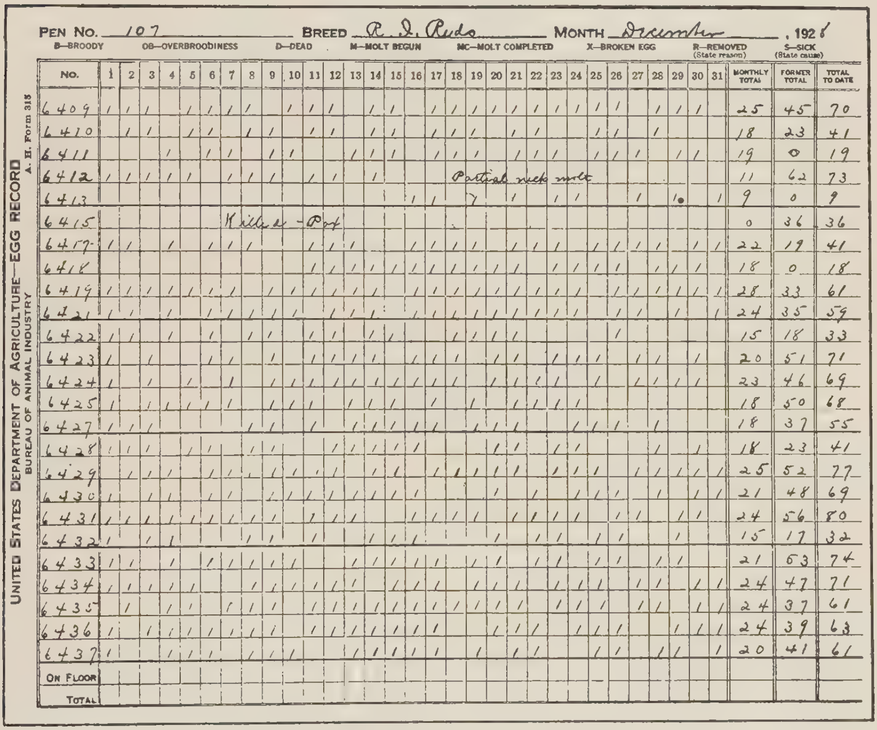
The fundamental object of the poultry breeder is to control and direct the process of reproduction in such a way that the product may have the highest possible value. The more complete is the control and the more definitely the process is directed towards the desired end, the greater is the success of the breeder. Since the poultry breeding industry rests upon a foundation of pure-bred pedigreed stock, it is very necessary to have a simple though complete system for keeping the pedigree records which permits of skillful, well-planned and carefully executed breeding.

Accuracy of Records.—The fundamental feature of a system of pedigree records is that any given pedigree or part of a pedigree may be entered or consulted after entry with the least possible expenditure of time and labor and the greatest possible accuracy. The system should be adapted to reducing the possibility of error to the minimum and it should be simple enough to be operated rapidly.

It may be said that the only certain and sure test of the worth of an animal as a breeder is found in the actual performance of that animal's progeny. It is highly important, therefore, that due consideration should be given by breeders to the value of the progeny test, for progeny testing serves as the foundation for the greatest improvement in breeding.

Records for Progeny Testing.—The first step in carrying out a scheme of progeny testing is to record on each egg the number of the hen that laid the egg. To be able to do this, trap nesting is necessary and, of course, the hens must have numbered leg bands, preferably sealed bands. As each hen is released from the trap nest, the number on her leg band is recorded on the egg and the production is recorded on the Egg Record form, shown in Fig. 39, which is suspended on the wall near the trap nests. The egg record form is 8 by 9½ in. and provides for the recording of the monthly production of 25 hens. The various notations at the top of the form should be noted, inasmuch as it is only when as complete information as possible is kept concerning the behavior of each hen that the poultry breeder knows all that he should know concerning his birds.

At the end of each month the records shown on the egg record form are transferred to Individual Egg Record forms, of which there is one for each hen, as shown in Fig. 40. It should be noted particularly that, among other things, the following features are readily observable in connection with the record of any hen: the age at which laying commenced, intensity of production, amount of broodiness, whether or not there are any long pauses in the records, persistency of production and the onset and duration of the molt. The individual egg record form is 6 by 9½ in., with a margin at the left for fitting in a patent loose-leaf binder.



UNITED STATES DEPARTMENT OF AGRICULTURE—EGG RECORD
BUREAU OF ANIMAL INDUSTRY
A. H. Form 318

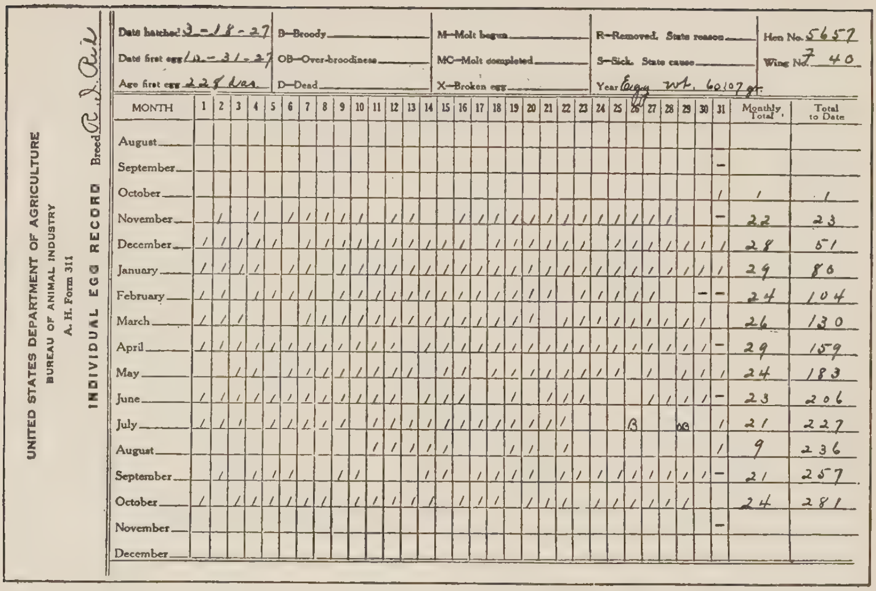
PEN NO. 107 BREED R. I. Reds MONTH December, 1926
B—BROODY OB—OVERBROODINESS D—DEAD M—MOLT BEGUN MC—MOLT COMPLETED X—BROKEN EGG R—REMOVED (State reason) S—SICK (State cause)

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Monthly Total	Former Total	Total to Date
6409	/	/	/		/	/	/	/		/	/	/		/	/		/	/	/	/	/	/	/	/	/	/		/	/	/		25	45	70
6410		/	/		/	/		/	/		/	/		/	/		/	/	/		/	/			/	/		/				18	23	41
6411				/		/	/		/	/			/	/	/		/	/	/		/	/	/		/	/	/		/	/		19	0	19
6412	/	/	/	/	/		/	/	/		/	/		/				Partial neck molt														11	62	73
6413																/	/		/		/		/	/			/		/•		/	9	0	9
6415							Killed - Pot																									0	36	36
6417	/	/		/		/	/	/			/	/	/			/	/	/	/		/	/	/		/	/	/	/		/	/	22	19	41
6418											/	/	/	/	/	/	/	/	/	/	/		/	/	/	/		/	/	/		18	0	18
6419	/	/	/	/	/	/	/		/	/	/	/	/	/		/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	28	33	61
6421	/	/		/		/	/	/	/	/		/	/	/		/	/	/	/	/	/	/	/	/		/	/		/		/	24	35	59
6422	/	/		/		/		/	/		/	/		/	/			/	/	/	/					/						15	18	33
6423	/		/			/	/		/		/	/	/	/		/	/	/		/	/		/	/	/		/	/		/		20	51	71
6424	/		/		/		/		/	/	/	/	/	/	/	/	/	/		/	/	/	/		/		/	/	/	/		23	46	69
6425	/		/	/	/	/	/		/	/	/		/	/	/		/		/		/	/	/	/								18	50	68
6427	/	/	/					/	/		/		/	/	/	/	/		/	/	/			/	/	/		/				18	37	55
6428	/	/	/		/	/		/	/			/	/	/	/	/				/	/		/	/				/		/		18	23	41
6429		/	/	/		/	/	/	/	/	/	/		/	/		/	/	/	/	/		/	/	/		/	/	/	/	/	25	52	77
6430	/		/	/		/	/		/	/	/	/	/	/	/	/				/		/		/	/	/		/		/	/	21	48	69
6431	/	/	/	/	/	/	/	/	/		/	/	/			/	/	/	/		/	/	/	/		/	/		/	/		24	56	80
6432	/		/	/				/	/		/			/	/	/				/		/	/		/	/			/			15	17	32
6433	/	/		/		/	/	/	/	/			/	/	/	/	/		/	/		/	/		/	/		/	/			21	53	74
6434	/	/	/	/	/			/	/	/	/	/	/		/	/	/		/	/	/		/	/	/		/	/		/	/	24	47	71
6435		/		/	/		/	/	/		/	/	/	/	/	/	/	/	/	/	/		/	/	/		/	/		/	/	24	37	61
6436	/		/	/	/	/	/	/	/		/	/	/	/	/	/	/			/	/	/		/	/	/			/	/	/	24	39	63
6437	/			/	/	/		/	/	/			/	/	/	/	/		/		/	/			/	/		/	/		/	20	41	61
On Floor																																		
Total																																		

FIG. 39.—The Egg Record is kept in the laying pen and contains the record of production of each bird for one month. Bird 6413 in the record shown here is a late maturing bird, since she has just commenced laying Dec. 16. Out of 25 birds, 14 laid 20 or more eggs each in December. The right-hand column gives the total number of eggs produced from the time that each bird commenced laying. (*U. S. Dept. Agr.*)

The real object in maintaining breeding records, however, is to be able to identify the progeny of all parents in order to see what kind of progeny each pair of birds produces. For this purpose a set of records must be maintained which will permit of tracing each egg from the time it is laid to the time it hatches into a chick and tracing each chick up to maturity and later if it is used as a breeder.

Having recorded the numbers on the eggs laid by the individual hens in the breeding pen, it is next necessary to hold the eggs until they are to be incubated. The eggs should be incubated as soon as possible after



UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF ANIMAL INDUSTRY
A. H. Form 311
INDIVIDUAL EGG RECORD Breed R. I. Red

Date hatched 3-18-27
Date first egg 10-31-27
Age first egg 228 Das.
B—Broody
OB—Over-broodiness
D—Dead
M—Molt begun
MC—Molt completed
X—Broken egg
R—Removed. State reason
S—Sick. State cause
Year Egg wt. 60.07 gr.
Hen No. 5657
Wing No. 7 40

MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Monthly Total	Total to Date
August																																	
September																															–		
October																															/	1	1
November		/		/		/	/	/	/	/		/	/			/	/	/	/	/	/	/	/	/	/	/	/	/			–	22	23
December	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/		/	/	/	/	/	/	/	28	51
January	/	/	/	/		/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	29	80
February	/	/		/	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/			–	–	24	104
March	/	/	/				/	/	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/		26	130
April	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	–	29	159
May			/	/		/	/	/	/	/	/	/	/		/	/		/	/	/	/	/	/	/	/		/		/	/	/	24	183
June	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/			/		/	/	/				/	/	/	/	–	23	206
July	/	/	/		/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/				B			OB		/	21	227
August											/	/	/	/	/				/	/		/									/	9	236
September		/		/	/	/			/	/				/	/		/	/	/	/		/	/	/	/	/	/	/	/	/	–	21	257
October	/		/	/	/	/	/	/		/	/	/	/	/		/	/	/		/	/	/		/	/	/	/	/	/			24	281
November																															–		
December																																	

FIG. 40.—The Individual Egg Record shows the number of eggs laid from the time that laying commenced to 364 days thereafter. Hen 5657 laid 21 or more eggs every month except August. She was broody for a few days in July and the mean weight of the egg she laid was 60.07 g., which is over standard weight, since 56.70 g. = 2 oz. (*U. S. Dept. Agr.*)

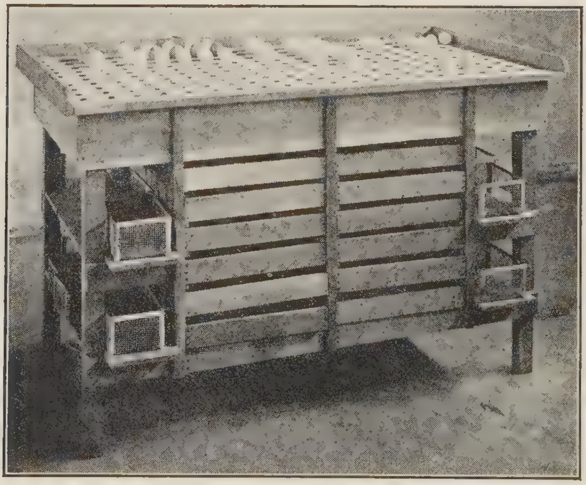
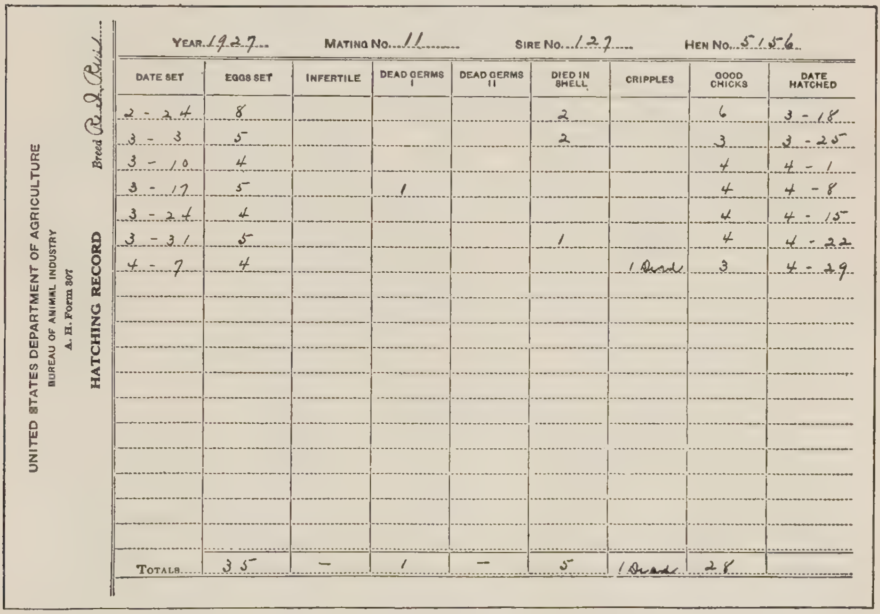


FIG. 41.—A table with drawers for holding hatching eggs from each breeding pen and indentations in the top of the table for sorting eggs by hen number. (*Photograph by U. S. Dept. Agr.*)

being laid, but much time will be saved if the eggs of a week's production from each hen are incubated together. An egg table fitted with drawers, such as shown in Fig. 41, is very suitable for holding eggs for incubation. The depressions running across the top facilitate in the sorting of the eggs laid by the different hens. Each hen's eggs are grouped together and, as the incubator is filled, the entries are made on the Hatching Record form shown in Fig. 42. This form will do for each hen for about 18 weeks, which is longer than the normal hatching season. The form is 6 by 9½ in.



UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF ANIMAL INDUSTRY
A. H. Form 307
HATCHING RECORD

Breed R. I. Red

YEAR 1927 MATING No. 11 SIRE No. 127 HEN No. 5156

DATE SET	EGGS SET	INFERTILE	DEAD GERMS I	DEAD GERMS II	DIED IN SHELL	CRIPPLES	GOOD CHICKS	DATE HATCHED
2 - 24	8				2		6	3 - 18
3 - 3	5				2		3	3 - 25
3 - 10	4						4	4 - 1
3 - 17	5		1				4	4 - 8
3 - 24	4						4	4 - 15
3 - 31	5				1		4	4 - 22
4 - 7	4					1 Dead	3	4 - 29
TOTALS	35	–	1	–	5	1 Dead	28	

FIG. 42.—The Hatching Record gives the results in fertility and hatchability of all eggs set each hatching season from each female breeder. Out of 35 fertile eggs set in 1927, hen 5156 had 28 good chicks hatch. (*U. S. Dept. Agr.*)

On the eighteenth day of incubation the eggs remaining in the incubator are all placed on the sorting table and each hen's eggs are grouped together for placing in the hatching bag or basket. Suitable hatching bags for holding five or six eggs may be made of strong cheesecloth or scrim, or a wire basket with a securely fitted top may be used. It is very important that every precaution be taken to keep each hen's eggs and the chicks hatching from them separate from the others. The hatching bag or basket should be carefully numbered.

Banding and Recording the Chicks.—After the chicks are hatched it is necessary to give each chick a numbered leg band or a numbered wing band. The bands should be numbered serially from one up to the number desired. If leg bands are used they will have to be changed from the

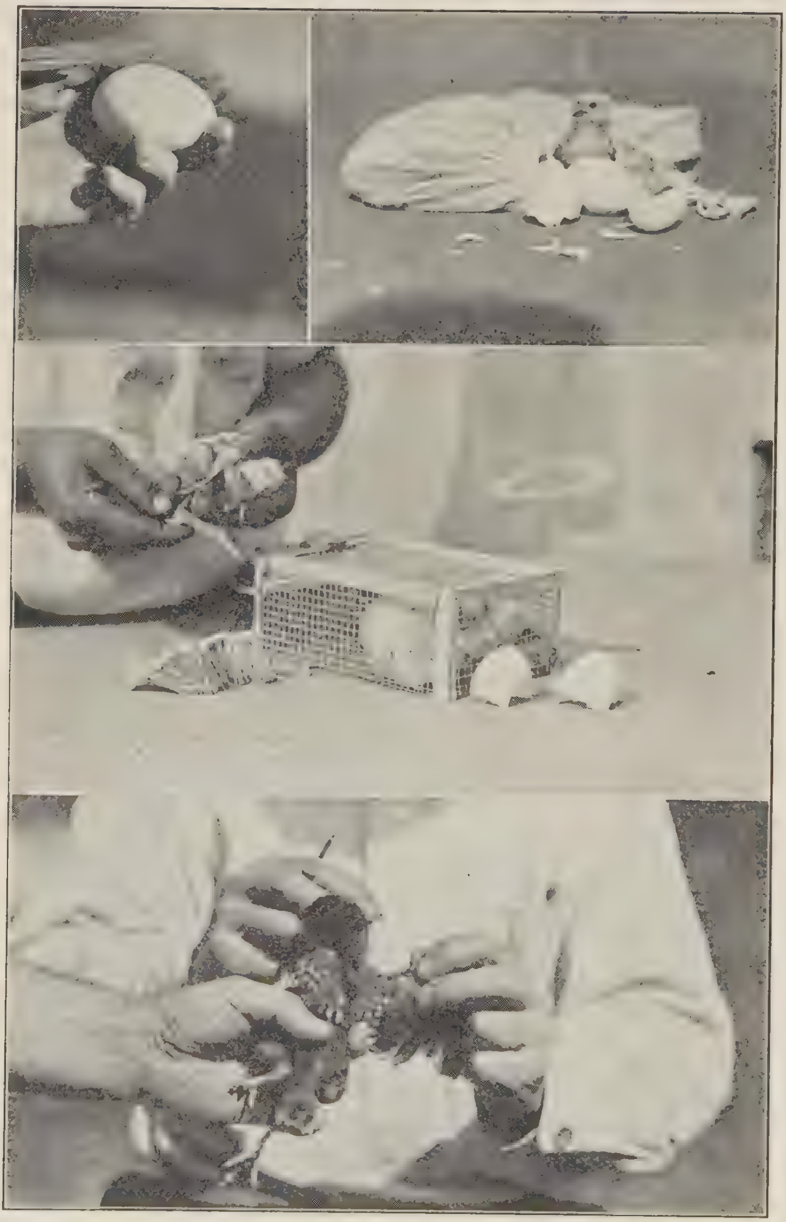
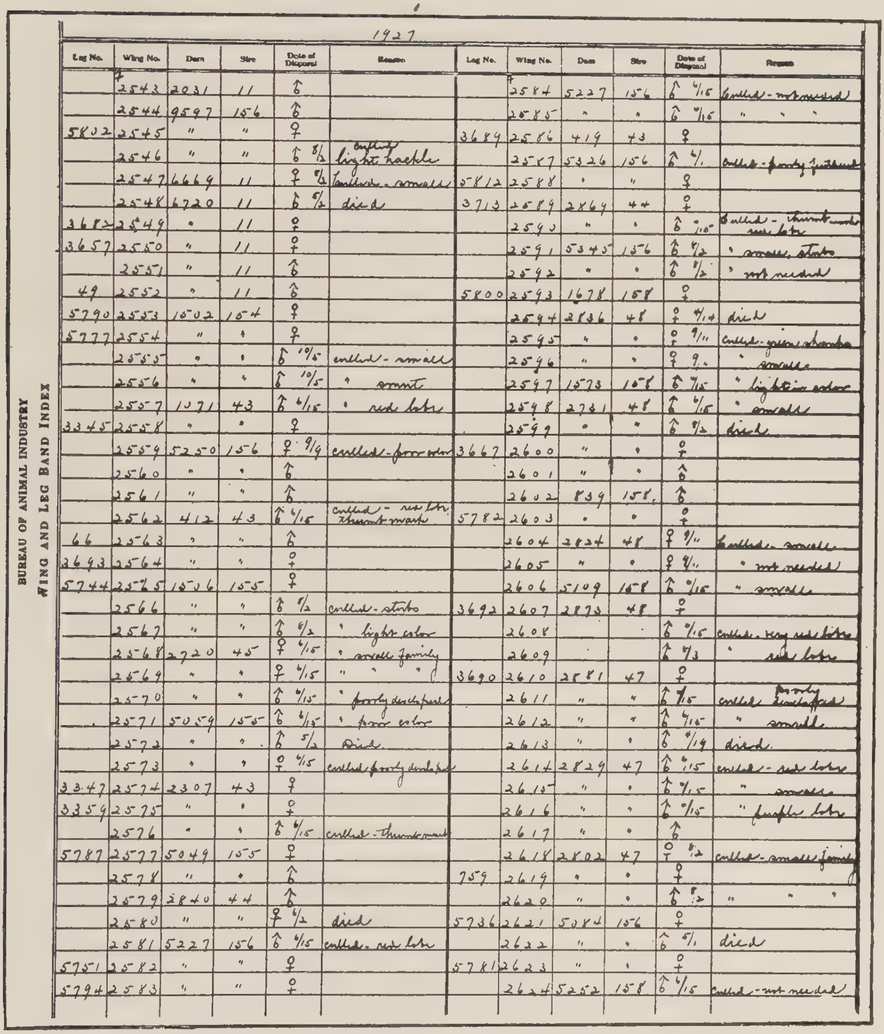


FIG. 43.—Some of the operations in pedigree breeding. Upper left, at time of laying, the egg is marked with the breeding pen number above and the hen number below. Upper right, a pedigree hatching sack containing the eggs from one hen only. Center, leg banding a chick taken from a pedigree basket. Bottom, wing banding a chick at 3 weeks of age. Chicks may be wing-banded at hatching time. (*Photograph by U. S. Dept. Agr.*)

legs and inserted in the wings when the chicks are three or four weeks old, or the chick leg bands may be changed for sealed wing bands. The



BUREAU OF ANIMAL INDUSTRY
WING AND LEG BAND INDEX

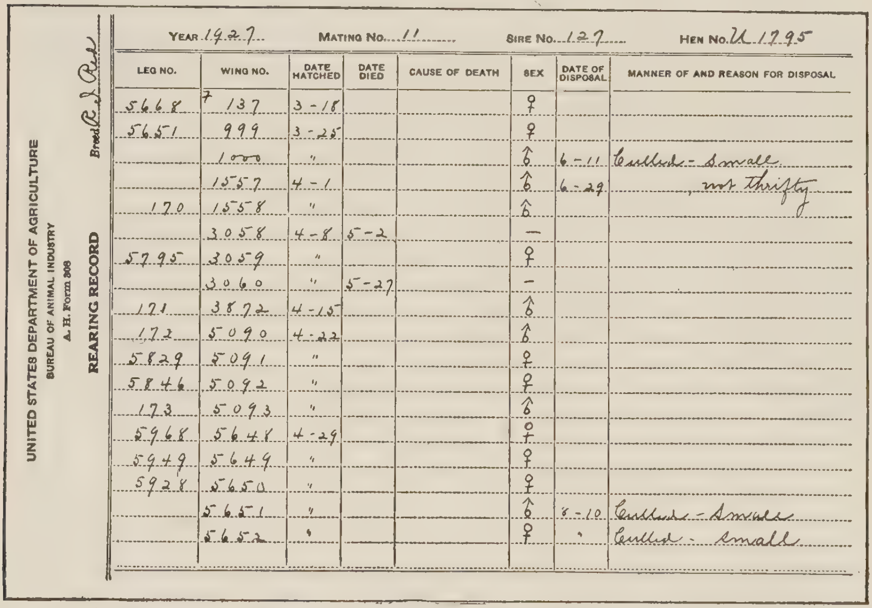
1927

Leg No.	Wing No.	Dam	Sire	Date of Disposal	Reason	Leg No.	Wing No.	Dam	Sire	Date of Disposal	Reason
	2543	2031	11	♂			2584	5227	156	♂ 6/15	culled - not needed
	2544	9597	156	♂			2585	·	·	♂ 6/15	" " "
5802	2545	"	"	♀		3689	2586	419	43	♀	
	2546	"	"	♂ 8/2	culling light hackle		2587	5326	156	♂ 6/1	culled - poorly feathered
	2547	6669	11	♀ 8/2	culled - small	5812	2588	·	"	♀	
	2548	6720	11	♂ 5/2	died	3713	2589	2864	44	♀	
3682	2549	·	11	♀			2590	"	·	♂ 6/15	culled - thumb mark, red lobe
3657	2550	"	11	♀			2591	5345	156	♂ 6/2	" small, stubs
	2551	"	11	♂			2592	·	·	♂ 6/2	" not needed
49	2552	·	11	♂		5800	2593	1678	158	♀	
5790	2553	1502	154	♀			2594	2836	48	♀ 4/14	died
5777	2554	"	·	♀			2595	"	·	♀ 9/11	culled - green shanks
	2555	·	·	♂ 10/5	culled - small		2596	"	·	♀ 9.	" small
	2556	·	·	♂ 10/5	" smut		2597	1573	158	♂ 7/15	" light in color
	2557	1071	43	♂ 6/15	" red lobe		2598	2731	48	♂ 6/15	" small
3345	2558	·	·	♀			2599	·	·	♂ 6/2	died
	2559	5250	156	♀ 9/9	culled - poor color	3667	2600	"	·	♀	
	2560	·	·	♂			2601	"	·	♂	
	2561	"	·	♂			2602	839	158	♂	
	2562	412	43	♂ 6/15	culled - red lobe, thumb mark	5782	2603	·	·	♀	
66	2563	·	·	♂			2604	2834	48	♀ 9/11	culled - small
3693	2564	"	·	♀			2605	"	·	♀ 9/11	" not needed
5744	2565	1506	155	♀			2606	5109	158	♂ 6/15	" small
	2566	"	·	♂ 6/2	culled - stubs	3692	2607	2873	48	♀	
	2567	"	·	♂ 6/2	" light color		2608		·	♂ 6/15	culled - very red lobe
	2568	2720	45	♀ 6/15	" small family		2609	·		♂ 7/3	" red lobe
	2569	·	·	♀ 6/15	" " "	3690	2610	2881	47	♀	
	2570	·	·	♂ 6/15	" poorly developed		2611	"	·	♂ 7/15	culled poorly developed
	2571	5059	155	♂ 6/15	" poor color		2612	"	·	♂ 6/15	" small
	2572	·	·	♂ 5/2	Died		2613	"	·	♂ 6/19	died
	2573	·	·	♀ 6/15	culled poorly developed		2614	2829	47	♂ 6/15	culled - red lobe
3347	2574	2307	43	♀			2615	"	·	♂ 6/15	" small
3359	2575	"	·	♀			2616	"	·	♂ 6/15	" purple lobe
	2576	·	·	♂ 6/15	culled - thumb mark		2617	"	·	♂	
5787	2577	5049	155	♀			2618	2802	47	♀ 6/2	culled - small family
	2578	"	·	♂		759	2619	·	·	♀	
	2579	2840	44	♂			2620	"	·	♂ 6/2	" " "
	2580	"	"	♀ 6/2	died	5736	2621	5084	156	♀	
	2581	5227	156	♂ 6/15	culled - red lobe		2622	"	·	♂ 5/1	died
5751	2582	"	"	♀		5781	2623	"	·	♀	
5794	2583	"	"	♀			2624	5252	158	♂ 6/15	culled - not needed

FIG. 44.—The Wing and Leg Band Index is divided into right and left halves. The chicks are banded at hatching time, their band numbers being written in the second column from the left. In the next two columns to the right are given the dam and sire of each chick. In the next column to the right, Date of Disposal, is indicated the sex of each chick and the date it was disposed of, with the reason for disposal in the next column to the right. In the extreme left-hand column of each half of the record there is inserted the leg-band number of each bird kept in the fall of the year. By means of this record the pedigree of any bird can be traced quite readily. (*U. S. Dept. Agr.*)

advantages in wing banding the chicks at hatching time are that it is at once permanent and the danger is avoided of causing lameness before the leg bands are enlarged or removed. For very valuable chicks a band may be inserted in each wing. Wing banding at hatching time, however, is more difficult than leg banding, which is usually practiced.

As the chicks are banded, the band numbers are entered in the Wing No. column of the Wing and Leg Band Index form shown in Fig. 44. The reason for putting the band number of the chick in the Wing No. column, even if the chicks are first banded on the leg, is that when the chicks are three or four weeks of age the leg bands are transferred to the wings. The band placed on each chick at hatching time is really the wing band by which the bird will be permanently identified for the rest of its life. The wing and leg band index form provides for the entry of 82 chick band numbers in the two sets of columns. It is understood, of course, that each sheet of this form will contain the chicks from a number of hens taken off from one hatch. The ancestry of each chick is indicated by the dam and sire numbers inserted in their appropriate columns. The purpose of the wing and leg band index form is to provide for the ready entry of the band numbers of the chicks and their parents at hatching time and to permit of entering the date of death of any chick during the growing period.



UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF ANIMAL INDUSTRY
A. H. Form 308

REARING RECORD

Breed R. I. Red

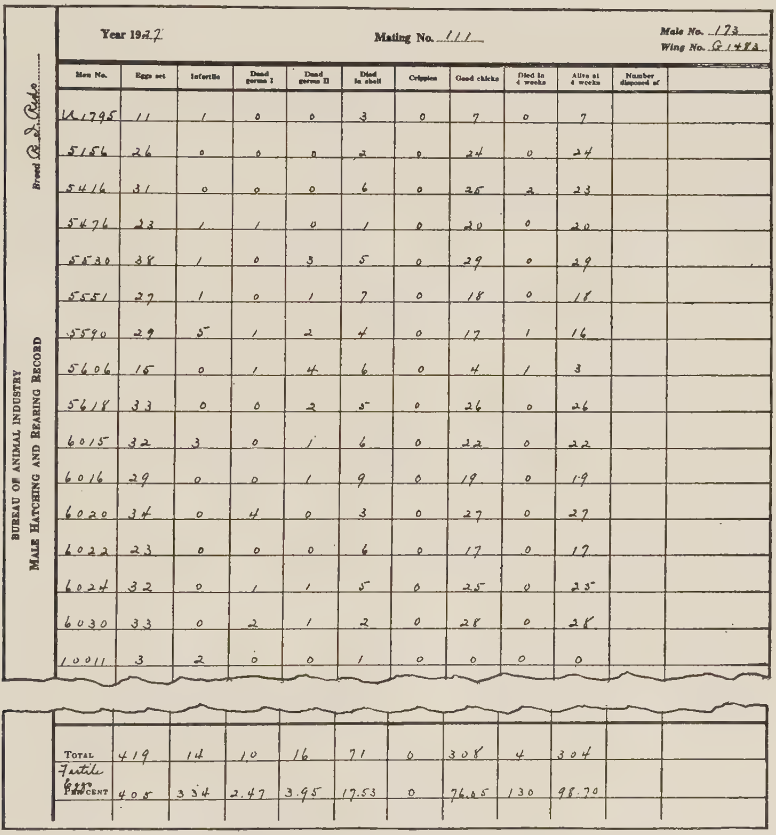
YEAR 1927 MATING No. 11 SIRE No. 127 HEN No. U 1795

LEG NO.	WING NO.	DATE HATCHED	DATE DIED	CAUSE OF DEATH	SEX	DATE OF DISPOSAL	MANNER OF AND REASON FOR DISPOSAL
5668	7 137	3-18			♀		
5651	999	3-25			♀		
	1000	"			♂	6-11	Culled - Small
	1557	4-1			♂	6-29	, not thrifty
170	1558	"			♂		
	3058	4-8	5-2		—		
5795	3059	"			♀		
	3060	"	5-27		–		
171	3872	4-15			♂		
172	5090	4-22			♂		
5829	5091	"			♀		
5846	5092	"			♀		
173	5093	"			♂		
5968	5648	4-29			♀		
5949	5649	"			♀		
5928	5650	"			♀		
	5651	"			♂	8-10	Culled - Small
	5652	"			♀	"	Culled - small

FIG. 45.—The Rearing Record contains the wing-band numbers and history of the progeny of each hen used as a breeder. Hen 1795 had 18 chicks hatched in 1927, 2 of which died before reaching maturity. Of the 16 chickens reared, 7 were males and 9 were females, 1 of the latter and 3 of the former being culled during the summer and fall. The figures in the extreme left-hand column show that 4 males and 8 females were leg banded in the fall of the year, the males to be used as breeders and the females to be put in the laying house. (*U. S. Dept. Agr.*)

The next step consists in entering the band numbers of all chicks hatched from each hen during the entire hatching period on the Rearing Record form shown in Fig. 45. This form is 6 by 9½ in.

The five record forms mentioned previously provide for the recording of complete information concerning the annual production of a hen, the incubation results of her eggs, the number of chicks that hatched and the number that died or were sold during the growing season.



BUREAU OF ANIMAL INDUSTRY
MALE HATCHING AND REARING RECORD

Breed R. I. Red

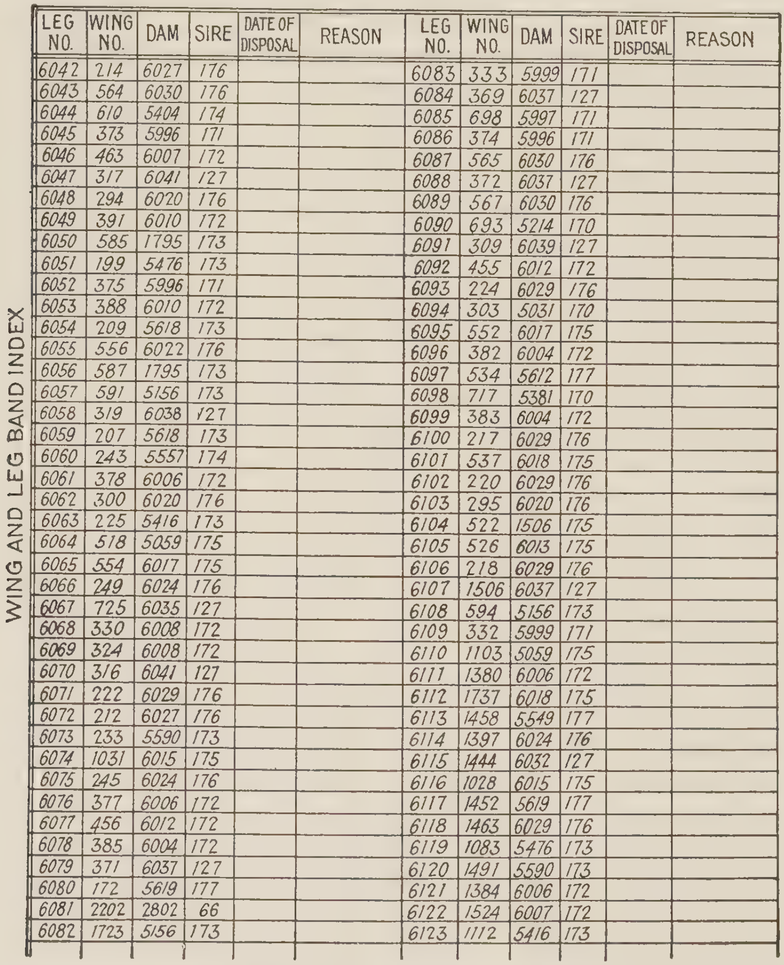
Year 1927
Mating No. 111
Male No. 173
Wing No. G1483

Hen No.	Eggs set	Infertile	Dead germs I	Dead germs II	Died in shell	Cripples	Good chicks	Died in 4 weeks	Alive at 4 weeks	Number disposed of	
U1795	11	1	0	0	3	0	7	0	7		
5156	26	0	0	0	2	0	24	0	24		
5416	31	0	0	0	6	0	25	2	23		
5476	23	1	1	0	1	0	20	0	20		
5530	38	1	0	3	5	0	29	0	29		
5551	27	1	0	1	7	0	18	0	18		
5590	29	5	1	2	4	0	17	1	16		
5606	15	0	1	4	6	0	4	1	3		
5618	33	0	0	2	5	0	26	0	26		
6015	32	3	0	1	6	0	22	0	22		
6016	29	0	0	1	9	0	19	0	19		
6020	34	0	4	0	3	0	27	0	27		
6022	23	0	0	0	6	0	17	0	17		
6024	32	0	1	1	5	0	25	0	25		
6030	33	0	2	1	2	0	28	0	28		
10011	3	2	0	0	1	0	0	0	0		
TOTAL	419	14	10	16	71	0	308	4	304		
Fertile Eggs PER CENT	405	3.34	2.47	3.95	17.53	0	76.05	130	98.70		

FIG. 46.—The Male Hatching and Rearing Record gives quite complete information regarding the number of eggs set, then fertility and hatchability in the case of each hen. The data of this record are of great value in determining the breeding worth of any male. (*U. S. Dept. Agr.*)

Since the breeding results of the males used are so important, it is necessary to record the results in hatchability and rearing obtained for all females to which each male is mated. Such results are entered in the Male Hatching and Rearing Record form shown in Fig. 46. This form is 11 by 11 in. and the information entered thereon constitutes a summary of the hatching and rearing results secured from each male. It will be noted that the fourth and third columns, respectively, from the right-hand side of the form, provide for the entry of the number of chicks that died and the number of chicks alive at four weeks of age. The period of four weeks is used, because it has been found in practice that under normal conditions practically all deaths during the growing season occur within that period.

Banding the Pullets.—In the fall of the year, as the young stock approaches maturity, the pullets that are to be placed in the laying houses and the cockerels that are to be used as breeders are banded with leg bands. In the case of the pullets the bands should be put on the left leg so that the numbers on the band are upside down when the bird is

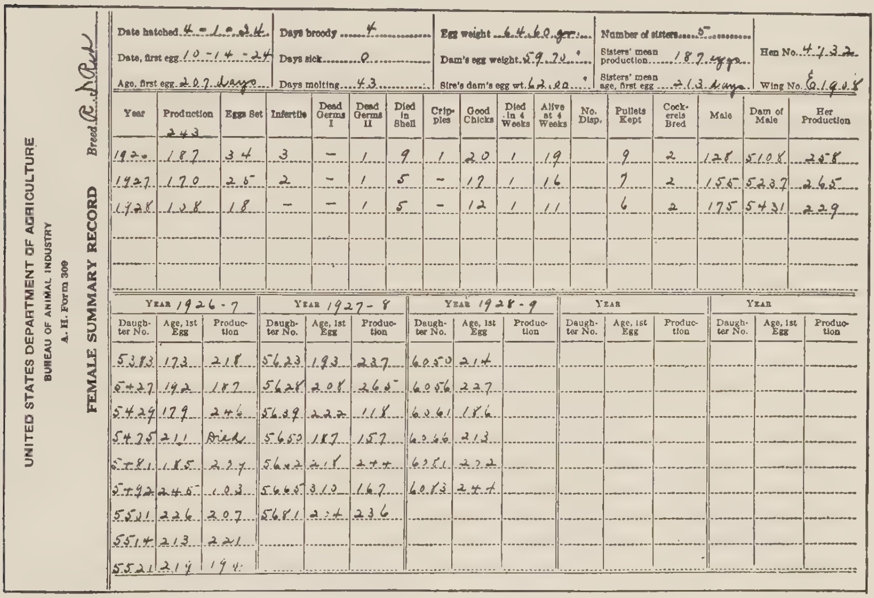


WING AND LEG BAND INDEX

LEG NO.	WING NO.	DAM	SIRE	DATE OF DISPOSAL	REASON	LEG NO.	WING NO.	DAM	SIRE	DATE OF DISPOSAL	REASON
6042	214	6027	176			6083	333	5999	171		
6043	564	6030	176			6084	369	6037	127		
6044	610	5404	174			6085	698	5997	171		
6045	373	5996	171			6086	374	5996	171		
6046	463	6007	172			6087	565	6030	176		
6047	317	6041	127			6088	372	6037	127		
6048	294	6020	176			6089	567	6030	176		
6049	391	6010	172			6090	693	5214	170		
6050	585	1795	173			6091	309	6039	127		
6051	199	5476	173			6092	455	6012	172		
6052	375	5996	171			6093	224	6029	176		
6053	388	6010	172			6094	303	5031	170		
6054	209	5618	173			6095	552	6017	175		
6055	556	6022	176			6096	382	6004	172		
6056	587	1795	173			6097	534	5612	177		
6057	591	5156	173			6098	717	5381	170		
6058	319	6038	127			6099	383	6004	172		
6059	207	5618	173			6100	217	6029	176		
6060	243	5557	174			6101	537	6018	175		
6061	378	6006	172			6102	220	6029	176		
6062	300	6020	176			6103	295	6020	176		
6063	225	5416	173			6104	522	1506	175		
6064	518	5059	175			6105	526	6013	175		
6065	554	6017	175			6106	218	6029	176		
6066	249	6024	176			6107	1506	6037	127		
6067	725	6035	127			6108	594	5156	173		
6068	330	6008	172			6109	332	5999	171		
6069	324	6008	172			6110	1103	5059	175		
6070	316	6041	127			6111	1380	6006	172		
6071	222	6029	176			6112	1737	6018	175		
6072	212	6027	176			6113	1458	5549	177		
6073	233	5590	173			6114	1397	6024	176		
6074	1031	6015	175			6115	1444	6032	127		
6075	245	6024	176			6116	1028	6015	175		
6076	377	6006	172			6117	1452	5619	177		
6077	456	6012	172			6118	1463	6029	176		
6078	385	6004	172			6119	1083	5476	173		
6079	371	6037	127			6120	1491	5590	173		
6080	172	5619	177			6121	1384	6006	172		
6081	2202	2802	66			6122	1524	6007	172		
6082	1723	5156	173			6123	1112	5416	173		

FIG. 47.—Wing and leg-band index form used for recording the wing and leg-band numbers of pullets kept. The dam and sire of each pullet is given, as well as the date of and reason for disposal, if such occurred. (*U. S. Dept. Agr.*)

standing; this makes it easier to read the numbers when the pullets are released from the trap nest. In the case of the cockerels the bands should be placed above the spur. The leg band numbers of all pullets are entered in serial order in the Leg No. column of the wing and leg band index form, size 11 by 11 in., as shown in Fig. 47, except that in this case the color of the form is different from that used for recording the chick band numbers. It will be seen, therefore, that the same form is used for entering the band numbers of the chicks as they are hatched and for entering the adult band numbers of the matured stock. Both forms constitute an excellent cross-reference for both wing-band and leg-band numbers, the cross-reference system being very useful in identifying any bird which may have lost either its wing or leg band. A double check is provided for tracing the pedigree of any bird at any time.



UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF ANIMAL INDUSTRY
A. H. Form 309
FEMALE SUMMARY RECORD
Breed R. I. Red

Date hatched 4-1-24
Date, first egg 10-14-24
Age, first egg 207 days
Days broody 4
Days sick 0
Days molting 43
Egg weight 64.60 gr.
Dam's egg weight 59.70
Sire's dam's egg wt. 62.00
Number of sisters 5
Sisters' mean production 187 eggs
Sisters' mean age, first egg 213 days
Hen No. 4732
Wing No. E1908

Year	Production 243	Eggs Set	Infertile	Dead Germs I	Dead Germs II	Died in Shell	Cripples	Good Chicks	Died in 4 Weeks	Alive at 4 Weeks	No. Disp.	Pullets Kept	Cockerels Bred	Male	Dam of Male	Her Production
1926	187	34	3	–	1	9	1	20	1	19		9	2	128	5108	258
1927	170	25	2	–	1	5	–	17	1	16		7	2	155	5237	265
1928	128	18	–	–	1	5	–	12	1	11		6	2	175	5431	229

Year 1926-7			Year 1927-8			Year 1928-9			Year			Year		
Daughter No.	Age, 1st Egg	Production	Daughter No.	Age, 1st Egg	Production	Daughter No.	Age, 1st Egg	Production	Daughter No.	Age, 1st Egg	Production	Daughter No.	Age, 1st Egg	Production
5383	173	218	5623	193	237	6050	214							
5427	192	187	5628	208	265	6056	227							
5429	179	246	5639	222	118	6061	186							
5475	211	Died	5650	187	157	6066	213							
5481	185	237	5662	218	244	6081	222							
5492	245	103	5665	310	167	6083	244							
5521	226	207	5681	234	236									
5514	213	221												
5521	219	194												

FIG. 48.—The Female Summary Record gives a great deal of information regarding each female used as a breeder, as well as information regarding her parents and sisters, that is of help in determining her breeding worth. The results in fertility and hatchability are shown for each year she is used as a breeder. The age of laying the first egg and the first-year production of each daughter produced each year are shown. (*U. S. Dept. Agr.*)

Summary Records.—The Female Summary Record form, shown in Fig. 48, provides for the entry of various items of major importance in determining her reproductive ability and her breeding worth from the standpoint of egg production. The form is 6 by 9½ in. The top of the form provides for the entry of important information concerning the hen herself and her sisters. For each year that the hen is bred the hatching results and the rearing results of her chicks are summarized, and the number of the male to which she is mated, his dam and her production are entered in the appropriate columns. On the lower half of the form the daughters kept each year, the date of the first egg and the pullet production of each pullet are entered in the three columns provided. The production of the hen herself as well as that of her sisters and her daughters is all given on this summary record form and, when the production of the dam of the male to which the hen was mated is also taken into consideration, a very good index is provided for determining the hen's real breeding worth.

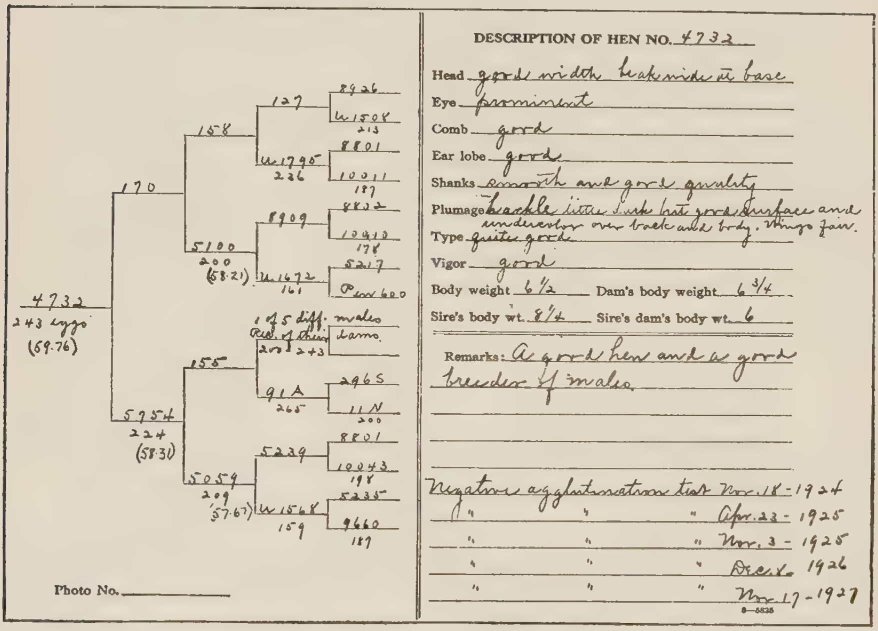

4732
243 eggs
(59.76)
170
5754
224
(58.31)
158
5100
200
(58.21)
155
5059
209
(57.67)
127
w1795
236
8909
w1672
161
1 of 5 diff. males
Rec. of their
200 243
91A
265
5239
w1568
159
8926
w1508
213
8801
10011
187
8822
10410
178
5217
Pen 600
dams.
2965
11N
200
8801
10043
198
5235
9660
187

Photo No.

DESCRIPTION OF HEN NO. 4732

Head good width beak wide at base

Eye prominent

Comb good

Ear lobe good

Shanks smooth and good quality

Plumage hackle little dark but good surface and undercolor over back and body. Wings fair.

Type quite good

Vigor good

Body weight 6 1/2 Dam's body weight 6 3/4

Sire's body wt. 8 1/4 Sire's dam's body wt. 6

Remarks: A good hen and a good breeder of males

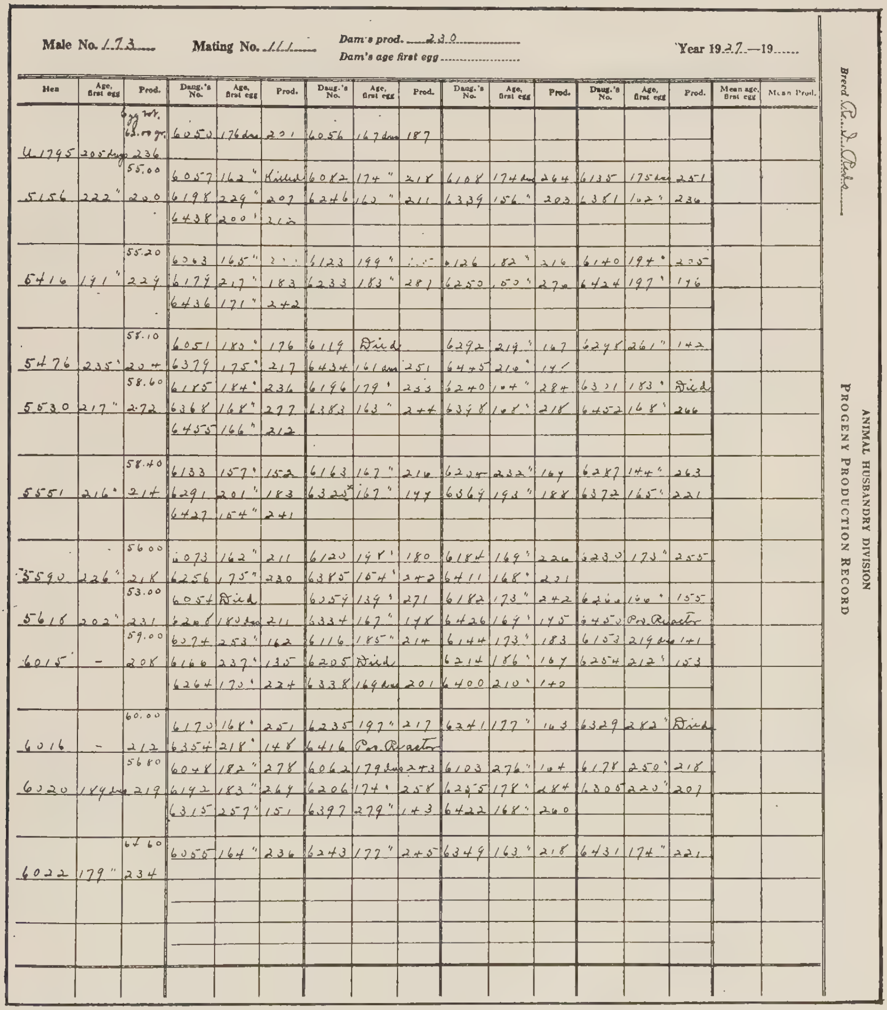
Negative agglutination test Nov. 18 - 1924
" " " Apr. 23 - 1925
" " " Nov. 3 - 1925
" " " Dec. 8. 1926
" " " Nov. 17 - 1927

8—5535

FIG. 49.—The pedigree of a female together with her description. Four generations of ancestors are shown, and in the case of each mating, the sire is shown above and the dam below, together with her first-year egg production and the mean size of her eggs, in brackets. Hen 4732 was of good color and a good breeder of males. She reacted negatively to the agglutination test for the pullorum disease on five different occasions. This record form is on the reverse side of that shown in Fig. 48, so that quite a complete history of each female is available on one sheet. (*U. S. Dept. Agr.*)

Further information concerning the hen is given on the reverse side of the "Female Summary Record" form, shown in Fig. 49. A fairly complete description of the hen is provided for as well as any additional remarks, and the pedigree of the hen to the fifth generation is given. The female summary record form, therefore, is a veritable encyclopedia of information concerning each hen bred, giving as it does her description, her pedigree, her performance, the production of her sisters, the production of dam of the sire of the progeny, and the production of the progeny.

Throughout all of the discussion on breeding practice, in Chap. X, the importance of the male has been emphasized and so it is well to provide a form upon which may be entered information concerning the male's breeding value. The Progeny Production Record form, shown in Fig. 50, gives the numbers of all hens to which each male is mated, the age of each hen when she laid her first egg, her production, and the num-



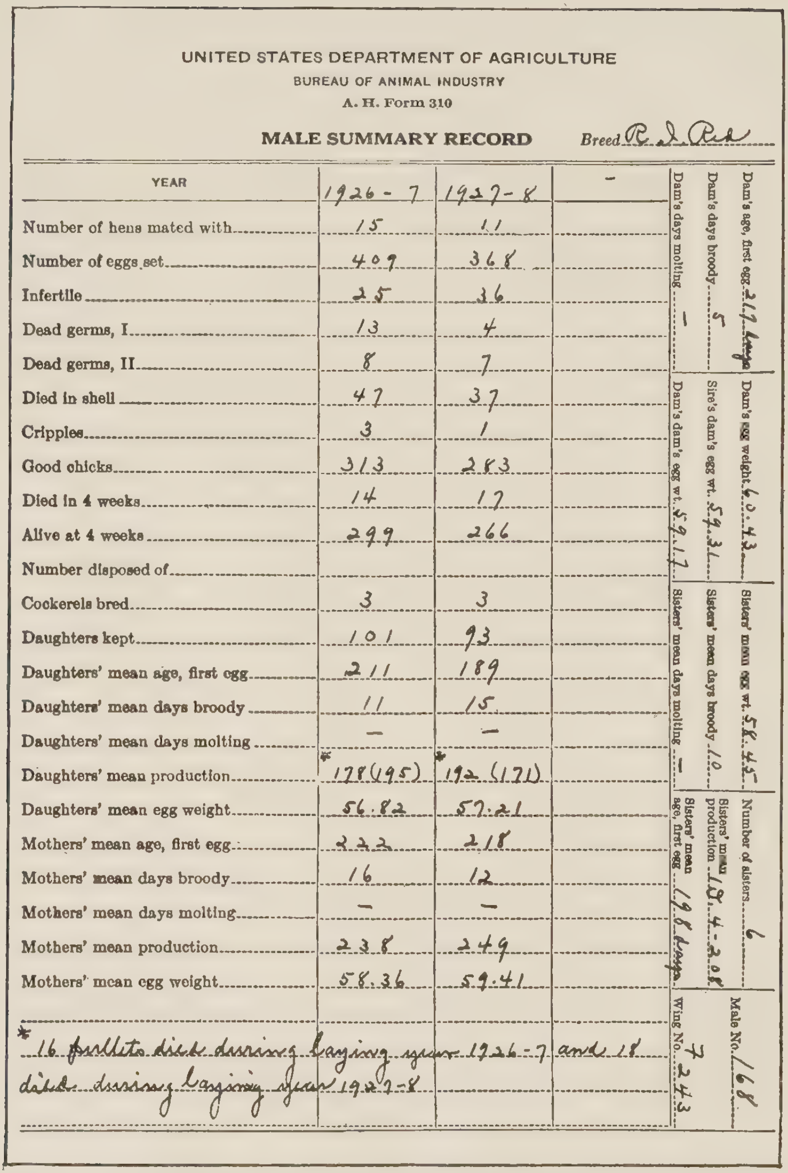
ANIMAL HUSBANDRY DIVISION
PROGENY PRODUCTION RECORD

Breed R. I. Reds

Male No. 173 **Mating No.** 111 *Dam's prod.* 230 *Dam's age first egg* ...... **Year** 1927—19......

Hen	Age, first egg	Prod.	Daug.'s No.	Age, first egg	Prod.	Daug.'s No.	Age, first egg	Prod.	Daug.'s No.	Age, first egg	Prod.	Daug.'s No.	Age, first egg	Prod.	Mean age, first egg	Mean Prod.
		Egg wt. 62.00 gr.	6050	176 das	201	6056	167 das	187								
4-1795	205 days	236														
		55.00	6057	162"	Killed	6082	174"	218	6108	174 das	264	6135	175 das	251		
5156	222"	200	6198	229"	207	6246	162"	211	6339	156"	203	6361	162"	236		
			6438	200"	212											
		55.20	6063	165"	[illegible]	6123	199"	[illegible]	6126	182"	216	6140	194"	205		
5416	191"	229	6179	217"	183	6233	183"	281	6250	150"	270	6424	197"	176		
			6436	171"	242											
		58.10	6051	180"	176	6119	Died		6292	219"	167	6298	261"	142		
5476	235"	204	6379	175"	217	6434	161 das	251	6445	216"	148					
		58.60	6185	184"	236	6196	179"	233	6240	164"	284	6321	183"	Died		
5530	217"	272	6368	168"	277	6383	163"	244	6398	168"	218	6452	168"	266		
			6455	166"	212											
		58.40	6133	157"	152	6163	167"	216	6226	232"	164	6287	144"	263		
5551	216"	214	6291	201"	183	6325	167"	177	6369	193"	188	6372	165"	221		
			6427	154"	241											
		56.00	6073	162"	211	6120	198"	180	6184	169"	226	6230	173"	255		
5590	226"	218	6256	175"	230	6385	164"	242	6411	168"	221					
		53.00	6054	Died		6059	139"	271	6182	173"	242	6266	166"	155		
5616	202"	231	6208	180 das	211	6334	167"	178	6426	167"	175	6450	Por. Reactor			
		59.00	6074	253"	162	6116	185"	214	6144	173"	183	6153	219 das	141		
6015	–	208	6166	237"	135	6205	Died		6214	186"	167	6254	212"	153		
			6264	170"	224	6338	169 das	201	6400	210"	140					
		60.00	6170	168"	251	6235	197"	217	6241	177"	163	6329	282"	Died		
6016	–	212	6354	218"	148	6416	Por. Reactor									
		56.80	6048	182"	278	6062	179 das	243	6103	276"	164	6178	250"	218		
6020	184 das	219	6192	183"	264	6206	174"	258	6255	178"	284	6305	220"	207		
			6315	257"	151	6397	279"	143	6422	168"	260					
		64.60	6055	164"	236	6243	177"	245	6349	163"	218	6431	174"	221		
6022	179"	234														

FIG. 50.—The Progeny Production Record gives the age at first egg and the first-year production of the pullets of each female to which the male in question was mated. The data in this record constitute the progeny test in determining the breeding worth of the male as well as that of the different females. (*U. S. Dept. Agr.*)



UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF ANIMAL INDUSTRY
A. H. Form 310

MALE SUMMARY RECORD Breed R. I. Red

YEAR	1926-7	1927-8	-
Number of hens mated with	15	11	
Number of eggs set	409	368	
Infertile	25	36	
Dead germs, I	13	4	
Dead germs, II	8	7	
Died in shell	47	37	
Cripples	3	1	
Good chicks	313	283	
Died in 4 weeks	14	17	
Alive at 4 weeks	299	266	
Number disposed of			
Cockerels bred	3	3	
Daughters kept	101	93	
Daughters' mean age, first egg	211	189	
Daughters' mean days broody	11	15	
Daughters' mean days molting	—	—	
Daughters' mean production	*178 (195)	*192 (171)	
Daughters' mean egg weight	56.82	57.21	
Mothers' mean age, first egg	222	218	
Mothers' mean days broody	16	12	
Mothers' mean days molting	—	—	
Mothers' mean production	238	249	
Mothers' mean egg weight	58.36	59.41	

*16 pullets died during laying year 1926-7 and 18 died during laying year 1927-8

Dam's age, first egg 217 days
Dam's days broody 5
Dam's days molting —
Dam's egg weight 60.43
Sire's dam's egg wt. 59.36
Dam's dam's egg wt. 59.17
Sisters' mean egg wt. 58.45
Sisters' mean days broody 10
Sisters' mean days molting —
Number of sisters 6
Sisters' mean production 183.4-208
Sisters' mean age, first egg 198 days
Male No. 168
Wing No. 7243

FIG. 51.—The Male Summary Record gives a great deal of information regarding each male used as a breeder together with information regarding his parents and sisters, all of which assists in determining his breeding worth. The record also contains information regarding the performance of his daughters and that of their dams. (*U. S. Dept. Agr.*)

ber of each daughter from all the hens, together with the age at first egg and production of each daughter and the mean age at first egg and mean production of all daughters from each hen. The information on this form, therefore, constitutes an application of the progeny test in the case of each male used as a breeder. This form is on the reverse side of the male hatching and rearing record, and, by consulting the information given in both forms, a very good idea is gained concerning the male's reproductive ability and his breeding worth.

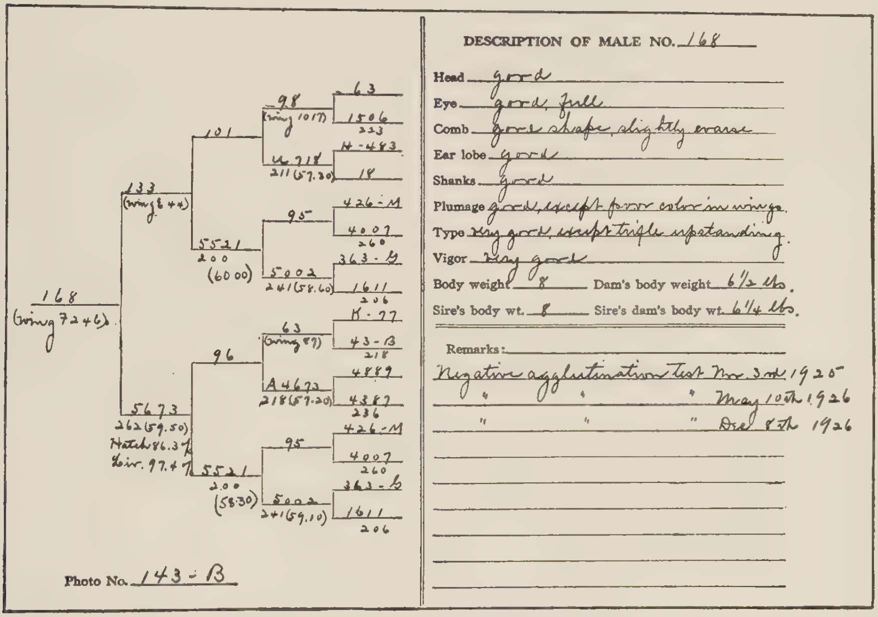

168
(wing 72+6)
133
(wing 844)
101
98
(wing 1017)
63
1506
223
H-483
U 718
211 (57.20)
18
5521
200
(60 00)
95
426-M
4007
260
363-G
5002
241 (58.60)
1611
206
5673
262 (59.50)
Hatch 86.3%
Liv. 97.4%
96
63
(wing 87)
K-77
43-B
218
4889
A 4673
218 (57.20)
4387
236
5521
200
(58.30)
95
426-M
4007
260
363-G
5002
241 (59.10)
1611
206

Photo No. 143-B

DESCRIPTION OF MALE NO. 168

Head good

Eye good, full

Comb good shape, slightly coarse

Ear lobe good

Shanks good

Plumage good, except poor color in wings.

Type very good, except trifle upstanding.

Vigor very good

Body weight 8 Dam's body weight 6½ lbs.

Sire's body wt. 8 Sire's dam's body wt. 6¼ lbs.

Remarks:

Negative agglutination test Nov. 3rd 1925

" " " May 10th 1926

" " " Dec 8th 1926

FIG. 52.—The pedigree of a male together with his description. The sire of male 168 was male 133 and the dam of male 168 was female 5673, whose first-year egg production was 262 eggs and their average weight 59.50 g. per egg, shown in brackets. Hen 5673 was a good breeder because 86.3 per cent of her eggs hatched and 97.4 per cent of her chicks were alive at 4 weeks of age. Under the heading Remarks it is to be observed that male 168 reacted negatively to the agglutination test for the pullorum disease on three occasions. This form is on the reverse side of that shown in Fig. 51, so that quite complete data are available regarding all males used as breeders. (*U. S. Dept. Agr.*)

All information of major importance concerning the male is recorded in the Male Summary Record form, shown in Fig. 51. This form is 6 by 9½ in. Important information concerning the dam and sisters of the male is given, as well as the hatching and rearing results secured each year and the performance of the daughters of the male and the performance of the mothers of the daughters. On the reverse side, shown in Fig. 52, is given a complete description of the male and his pedigree so that the male summary record form taken as a whole constitutes a veritable encyclopedia of information concerning each male used as a breeder.

The Value of Records.—In conclusion, it may be said that the system of pedigreeing poultry outlined above provides for a progressive entry of all records, one stage leading logically to a succeeding stage. The system is a simple one though it provides for the entry of all desired information and with a reasonable amount of care the possibility of error is reduced to the minimum. The significance of the progeny test is made clear, the progeny production entries being one of the chief features of the system. All in all, the system provides the breeder with a means of directing and controlling his breeding operations without which the greatest progress could hardly be achieved.

Various other appliances and methods for pedigree poultry breeding are described by Pearl and Surface (1908), Alder and Egbert (1918), Gowen (1919), Lippincott (1923, 1927), Jull (1923*c*) and Callenbach (1927).

CHAPTER XII

EMBRYO DEVELOPMENT AND HATCHABILITY

Perhaps the greatest and most far-reaching theme that has ever occupied the minds of men is the problem of development. The development of the chicken from the egg is a phenomenon of such universal occurrence that it is accepted as a matter of course, something requiring no explanation. But who is there who can tell *how* stage gives rise to stage as the chick develops in three weeks from a minute transparent spot on the surface of the yolk of the egg?

THE DEVELOPMENT OF THE CHICK

The normal incubation period of the egg of the chicken is 21 days. Bergoldt (1917) has determined that the incubation period for each species of birds is of a definite duration and that it can be shortened with extreme difficulty under artificial methods of incubation but that it can be lengthened somewhat with ease. It has been found, however, that eggs of the lighter breeds, such as Leghorns, usually hatch a few hours earlier than eggs of the heavier breeds, such as Plymouth Rocks, when conditions of incubation for both kinds of eggs are identical. For all practical purposes, however, the incubation period of all chicken eggs may be said to be 21 days.

A discussion of the intricate stages through which the embryo passes during the incubation period would be of immense interest to the specialist in incubation problems but only of indirect interest to the great majority of students in poultry husbandry. The specialist is referred to such excellent works as V. Baer (1837), Foster and Balfour (1883), Duval (1889), Keibel and Abraham (1900), Minot (1903), Kellicott (1913) and Lillie (1919). The general student of poultry husbandry should have sufficient knowledge of the development of the chick to enable him to appreciate the significance of some of the more important biological factors affecting hatchability. For this purpose a very brief discussion, taken largely from Curtis and Guthrie (1927), of the more important stages in the development of the embryo is presented here.

Development before Laying.—At the time the fertile egg is laid, the germinal disc has undergone a certain amount of cleavage so that it contains a number of cells, as shown in Fig. 53 *C*. The cleavage process of the germinal disc continues and soon gives rise, through a process known as gastrulation, to a structure having two layers of modified

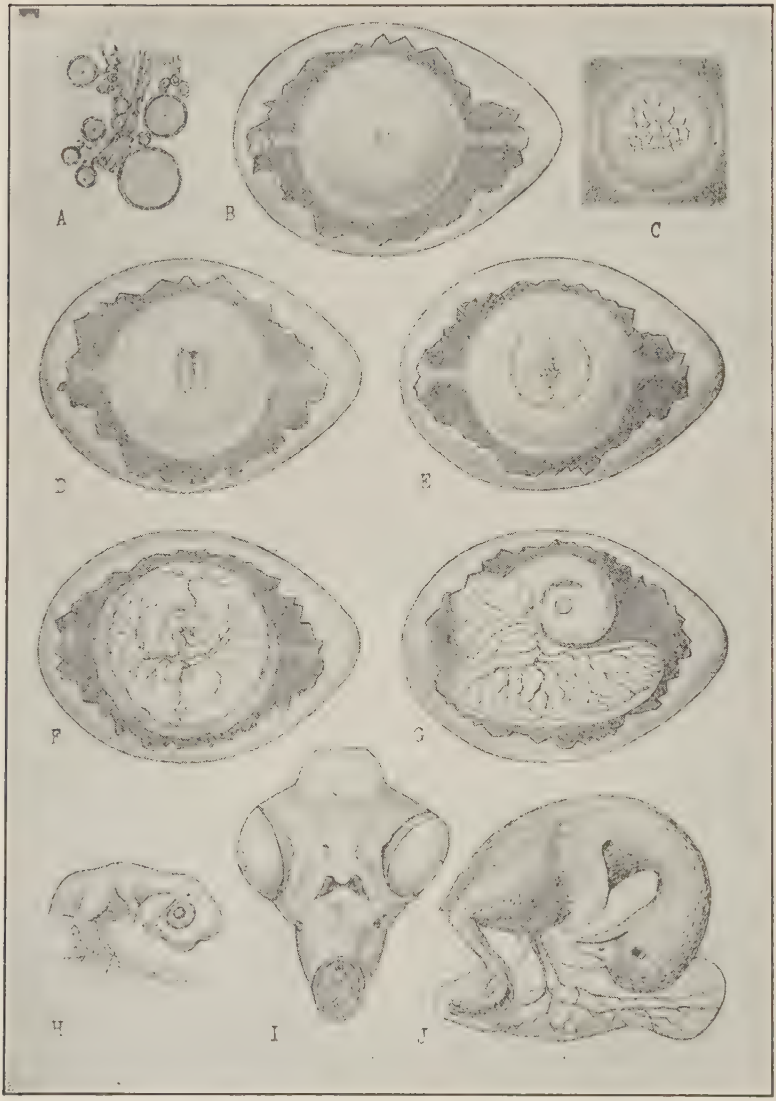


Fig. 53.—The development of the chick. *A*, part of the ovary showing ova in different stages of development. *B*, the fertilized egg at time of laying. *C*, early cleavage of the blastoderm. *D*, egg opened to show the late neural-fold stage and extension of blastoderm over yolk. *E* and *F*, stages during which the circulation is becoming established as the blastoderm extends further over the yolk. The allantois appears as a bladder-like outgrowth at the posterior end of the embryo in *F*. *G*, stage in which the allantois has enlarged and the yolk, surrounded by the yolk sac, has become reduced. In *F* and *G* the amnion is shown closely surrounding the embryo. *H*, later stage showing yolk stalk. *I*, front view of head, showing eyes, nasal openings, mouth and ears. *J*, a stage shortly before hatching, showing yolk stalk and remains of yolk. (*Photograph by Curtis and Guthrie Redrawn from Duval.*)[1]

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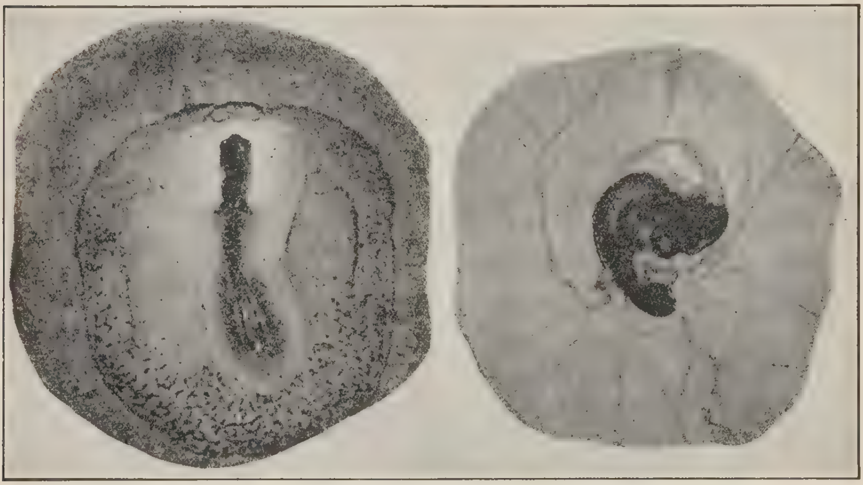
[1] Curtis and Guthrie, "Text-book of General Zoology." By permission of John Wiley & Sons, Inc., publishers.

cells, the outer layer comprising the ectoderm and the inner layer the entoderm. At this stage of development the blastoderm, as it is now called, is thinner and more transparent in its central portion, called the "area pellucida," and thicker around its margin, called the "area opaca," the two stages being shown in Fig. 53 *B* and also visible to the naked eye when a fertile egg is opened. The axis of the blastoderm lies at approximately right angles to the long axis of the egg. The cleavage process is arrested when the egg is laid but proceeds again when the egg is subjected to the proper temperature. According to Edwards (1902), if the temperature is below 68° F. the development of the embryo is completely arrested.

Development during Incubation.—When the egg is placed under proper conditions of incubation, the blastoderm develops rapidly, the primitive streak appearing in the area pellucida during the first 12 hours of incubation. The blastoderm gradually extends over the surface of the yolk and gives rise to the formation of the embryo, as shown in Fig. 53 *D* to *F*. The two-layered structure soon gives rise to a three-layered structure, the mesoderm arising between the ectoderm and the entoderm. As development proceeds certain folds develop, surrounding the embryo so that it is enclosed in an inner membrane, called the "amnion," and an outer membrane, called the "chorion," each composed of ectoderm and mesoderm. The amnion contains a fluid in which the embryo is embedded (see Fig. 53). By this time there has developed from the posterior portion of the hind gut an outgrowth known as the "allantois," shown in Fig. 53 and quite visible through the shell when the egg is tested on the seventh day of incubation. As the embryo increases in size, the allantois extends farther and farther until its outer surface comes into close contact with the inner surface of the chorion. "As the albumen of the egg becomes reduced, the allantois is closely applied to the inner surface of the chorion, which in turn lies against the shell membrane and shell, and thus becomes a respiratory and excretory organ by means of which oxygen and carbon dioxide are received and discharged." Curtis and Guthrie (1927). The allantois also absorbs albumen which serves as nourishment for the embryo (Lillie, 1919).

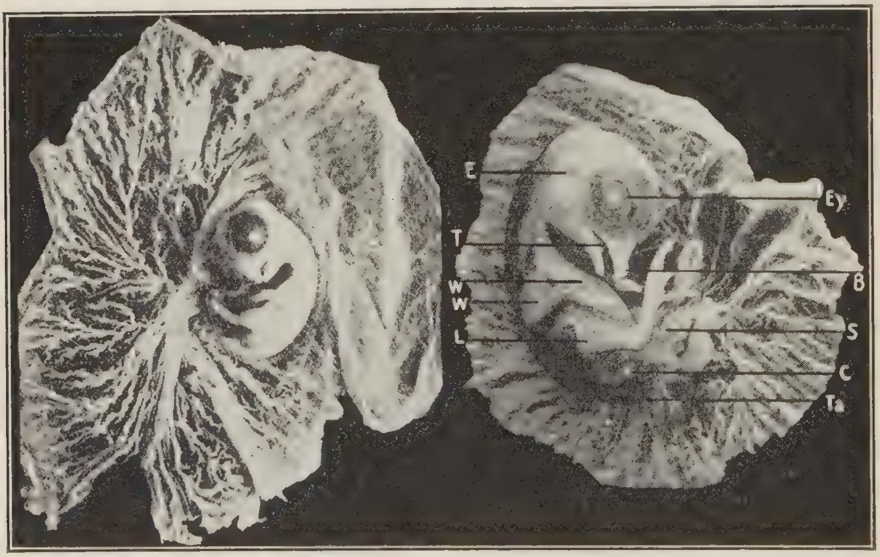
The development of other structures such as eyes, nose, wings, legs and internal organs is not discussed here because their development probably does not affect hatchability, except in the case of monstrosities and embryos whose heads and feet are so developed that emergence from the shell is impossible. A very good idea of the development of the external organs may be gained by examining Fig. 54 *A*, *B*, *C* and *D*, all after Evans (1923).

By the fourteenth day of incubation the axis of the embryo is parallel with the axis of the egg so that when the chick is fully formed the head is toward the large end of the egg. The albumen of the egg has been almost the sole source of nourishment for the embryo for the first two weeks, after which the yolk serves principally as the source of nourishment. The yolk, carried by the blood, is absorbed by portions of the walls of the yolk sac which surrounds the yolk, the latter being in direct



A *B*

Fig. 54.—*A*, embryo of 36 hours incubation. *B*, embryo of 90 hours incubation; note the well-defined allantois and blood vessels. (*After Evans.*)[1]



C *D*

Fig. 54.—*C*, embryo of 8 days incubation. *D*, embryo of 11 days incubation seen from right side: *B*, beak; *C*, cloacal elevation; *E*, ear; *Ey*, eye; *L*, leg with toes complete; *S*, stalk of allantois; *T*, tongue; *Ta*, tail; *W*,*W*, wing. (*After Evans.*)[1]

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[1] Evans, Ernest, "The Biology of Birds." By permission of John Dixon, Ltd., publishers.

connection with the embryo by means of the yolk stalk. The yolk sac enters the body of the embryo usually on the nineteenth and twentieth days and the development of the chick is completed.

Hatching Time.—Up to hatching time respiration has taken place by means of the allantois but when the beak is thrust into the air sac of the egg the lungs begin to function and there is thus a marked change in the nature of the respiration. The beak, equipped with a horny cap on the upper mandible, pips a circle around the large end of the shell while the embryo has been slowly revolving within the shell. Pohlman (1919) describes two muscles in the neck of the chick, musculus biventor and musculus spinalis, which are largely instrumental in enabling the chick to exert enough pressure with its beak to break through the shell.

Twenty-one days have witnessed the transformation of the fertile egg into a fully formed chick, which leaves behind, as remnants, the shell, the shell membranes and the membranes of the allantois and chorion.

PHYSIOLOGICAL CHANGES DURING THE DEVELOPMENT OF THE EMBRYO

Concerning the physiological changes that take place during the development of the embryo, it may be said that this field is being just entered upon by a number of workers but enough has been done to emphasize the significance of the various factors involved. A very comprehensive survey of the entire field is given by Needham (1925) in which he deals with the chemical changes during the early periods of cell division and during the later development. Reference is made to the existing lack of knowledge of some of the more important constituents of the egg and to the indefiniteness of morphological boundaries during embryonic development as contributing a major difficulty in determining

> . . . how far chemical processes are influenced and changed by the conditions of active growth and differentiation found in embryonic life.
>
> These, then, are some of the chief difficulties in the path of biochemical embryology. But the rewards of such study seem worth the trouble without a doubt. The avian egg is a closed system for 21 days; it loses about 3 litres of CO_2 (carbon dioxide) and a good deal of water, but no volatile nitrogenous compounds; it absorbs oxygen. During that time, from the simple yolk and white of the egg interior, there evolves the complete chick; with its hemoglobin, its feather-pigments and its multifarious tissue-constituents. The transformation is perhaps more dramatic than any other process in nature, if we except the metamorphosis of insects. And the difficulties are not insuperable. Moreover, bacteria, which in the adult animal "line every natural approach" are absent or almost so from the fertile egg. No food or excreta have to be analyzed. We deal with a closed system.

GENERAL PHYSICAL AND CHEMICAL CHANGES DURING EMBRYONIC DEVELOPMENT

Among the outstanding physical changes taking place during incubation is the loss in weight of the egg, shown by Prevost and Dumas (1825) to amount to about 5 g., the total weight of a normal-sized hen egg being approximately 57 g. Murray (1925*b*), however, points out that the loss in the water content during incubation is determined largely by the humidity of the atmosphere in the egg chamber. Dunn (1922–1923, 1923*d*, 1923*e*, 1924*c*) studied the matter much more intensively and found that the loss in weight is affected not only by the humidity of the atmosphere surrounding the eggs but also by the temperature of the incubator chamber. He also found that the loss in weight in large eggs is relatively less than in small eggs, a fact first observed by Atwood (1901), and that loss in weight varies considerably among eggs from different hens as well as among eggs of the same hen, due largely to differences in the porosity of the shell. Murray (1925*a*) found that the thickness and surface area of the shell and the amount of heat produced by the embryo during development influence the decrease in the weight of the egg during incubation. Gilbert (1894) and Laurie (1911) both found that the loss in weight in white-shelled eggs is greater than in brown-shelled eggs.

Mitchell, Hamilton and Card (1925), in a study of the composition of gains made by embryos, drew the following conclusions as reported in the *Experiment Station Record* (vol. 56, No. 5, p. 270):

> In continuing the study of the changes in the composition of White Plymouth Rocks during growth, 10 fertile eggs were dissected and analyzed on each day of incubation from the fourth to the twenty-first days as well as fresh eggs and chicks of from 1 to 3 days of age. The results showed that the dried weight of the embryo increased rapidly at about the twelfth day of incubation, reaching a maximum on the sixteenth day, and was followed by a retardation in the rate of growth on the seventeenth day. During incubation the weight of the eggs decreased 11 g., the weight of the dry substance about 3.5 g., and the energy value about 28 calories. A distinct transfer of calcium from the shell to the embryo was indicated.

Changes in White and Yolk.—During the incubation of fertile eggs the albumen increases in viscosity, while, in the yolk, viscosity decreases rapidly till the fifth day after which it rises until the end of incubation, according to Bellini (1907). The yolk gains water at the expense of the white. This phenomenon may be correlated with the change in osmotic pressure, Bialaszewicz (1912) having demonstrated that at the beginning of incubation the yolk is very much hypertonic to the albumen but becomes less so as development proceeds. Needham (1925) observes that the osmotic pressure of the developing chick rises steadily and, in his opinion, this may indicate an increased metabolic vigor. He observes further, however, that the increased ash content as a result of ossification, as demonstrated by von Baer (1837) may also account in part for the rise in the osmotic pressure of the chick.

At the beginning of incubation the yolk is acid and the albumen alkaline, but at the end of incubation the yolk is neutral or slightly alkaline and the albumen is distinctly acid, according to Aggazzotti (1913*a*). The trend toward the acidity on the part of the albumen is of significance in relation to the increased production of carbon dioxide by the embryo as development proceeds.

Bohr and Hasselbalch (1900) and Langworthy (1903) made observations on the heat production of the developing embryo and found that it follows closely the increase in carbon dioxide production as well as the increase in the weight of the embryo.

The Respiration of the Developing Embryo.—It has long since been determined that the developing embryo gives off carbon dioxide and takes in oxygen. Early workers, however, believed otherwise, but their results were disproved by St. Hilaire (1820), Schwann (1834, 1835), Marshall (1840), Darcste (1855), Gerlach (1881), Dusing (1884) and Preyer (1885), the last of whom demonstrated that the embryo respires long before the development of the chick's lungs.

Baudrimont and St. Ange (1847) and Dareste (1855) observed that the air space, usually formed in the large end of the egg, serves an important function in respiration. The general conclusion was that aqueous transpiration took place over all parts of the egg, but gaseous exchange took place only by way of the allantoic membrane and the air space. Aggazzotti (1914) observed that the percentage of carbon dioxide in the air space remained constant till the sixth day of incubation after which it rose rapidly, whereas the oxygen percentage began to drop steadily after the tenth day only. The results of the work of Dareste (1855), Gerlach and Koch (1882), Féré (1894), Dunn (1923*f*) and Byerly (1926) go to show that the embryo will develop normally if the entire egg, except the upper part containing the air space, is coated with a varnish or with water glass, and that as much as one-half of the shell, including the air space, may be coated without apparently affecting normal development. Lippincott and De Puy (1923) secured fair hatches from eggs lying in ½ in. of water while being incubated.

That the development of the embryo can proceed for a few days outside of the shell has been demonstrated by Preyer (1885), Féré (1900), Loisel (1900), Paton (1911) and Vogelaar and van den Boogert (1925), the last two investigators securing embryo development in vitro up to five days, at which time a large vascular area and an embryo are visible.

Carbon Dioxide Increases.—The results of the work of Bakounine (1895), Hasselbalch ((1900, 1902), Bohr and Hasselbalch (1900) and Aggazzotti

(1914) showed that, whereas the carbon dioxide in the air space of the egg increases only four or five times during incubation, the carbon dioxide produced by the embryo increases about forty times. In this connection Needham (1925) makes the interesting observation that the shell and the shell membrane above the air space become progressively more permeable as embryonic development proceeds.

As the embryo develops, the amount of carbon dioxide given off increases and the amount of oxygen required also increases. The ratio of the carbon dioxide given off to oxygen consumed is known as the respiratory quotient. Bohr and Hasselbalch (1900, 1902, 1903) observed that on the fifth day of incubation the respiratory quotient was 0.9 after which it speedily declined to 0.71 on the ninth day, thereafter remaining constant. Their results were confirmed, for the most part, by Lussanna (1905).

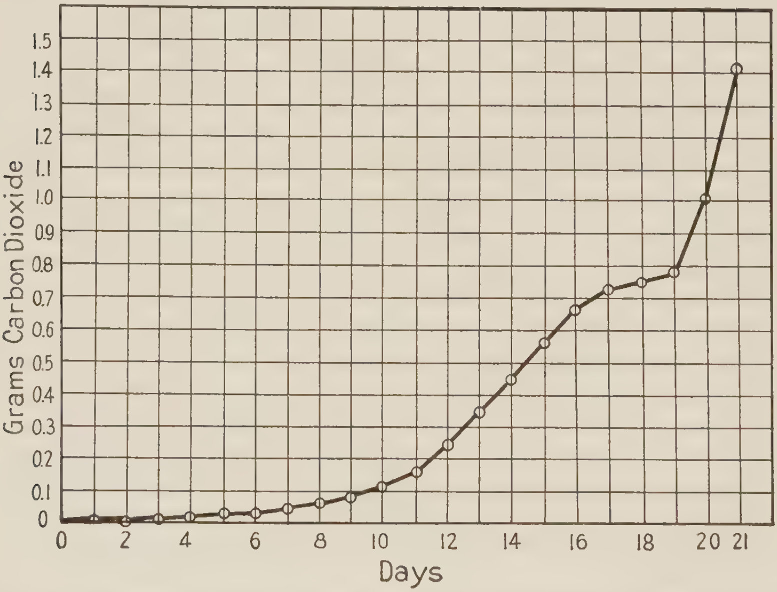

Fig. 55.—The amount of carbon dioxide given off per egg per day during incubation. (*Atwood and Weakley*, 1924.)

An insufficient supply of oxygen either kills the embryo in the early stages of development or produces abnormal chicks. Wesselkin (1913) demonstrated that eggs incubated in an atmosphere containing from 10 to 15 per cent oxygen produced embryos that lived for about 72 hr. only and the embryos were abnormal. This is quite interesting in view of the fact that the atmosphere ordinarily contains approximately 21 per cent of oxygen.

Several workers, Bohr and Hasselbalch (1900), Lamson and Edmond (1914), Atwood and Weakley (1915, 1924) and Murray (1925*a*) have all made determinations of the amount of carbon dioxide given off by the embryo during incubation. The results are not in entire agreement, which may have been due to the fact that the developing embryos upon which the observations were made by the various investigations were not in comparable stages of development from day to day. The curves in Fig. 55 show the trend of carbon dioxide elimination throughout the period of incubation.

Just how important it is to determine precisely the amount of carbon dioxide given off daily by the developing embryo is difficult to say. Results have been secured, for instance, that go to show that the developing embryo can tolerate a rather wide range of carbon dioxide content in the atmosphere of the egg chamber. This phase of the problem is discussed under the heading of the ventilation of incubators.

The Metabolism of the Developing Embryo.—Among the physiological changes occurring during embryonic development probably the most important are those which take place in the utilization by the developing embryo of the different substances contained in the egg. The egg is composed of carbohydrates, fat, protein and minerals and the shell is largely composed of calcium. These substances are utilized by the embryo during its development but at different rates during development, as shown by the results of various workers.

Among the earliest studies on the metabolism of the developing embryo are those of Liebermann (1888), who, however, made no attempt to follow the changes in the yolk apart from the albumen and the fluids of the amnion and the allantois. Riddle (1916*b*) showed that up to the twelfth day of incubation the various solids of the yolk are utilized by the embryo in approximately equal proportions. Riddle also determined that in the egg at 10 days of incubation there was approximately 10 per cent more moisture in the yolk than in the yolk of an unincubated egg, but at the time of the seventeenth day of development there was approximately 3 per cent less moisture in the yolk than in that of the unincubated egg. This corroborates the earlier findings of Parke (1871).

Needham (1926) has shown that the developing embryo secures its energy from three successive sources, carbohydrates, then proteins and lastly, fat.

Carbohydrate Metabolism.—Carbohydrate metabolism has its chief importance at the beginning of development, when the various organs of the embryo are taking shape. There appears to be a close correlation between the utilization of sugar by the embryo and its respiratory quotient during the first five days. The metabolism of carbohydrates in the chick embryo is summarized by Needham (1927) in the following brief account:

During the first week of incubation, it is noted that the amount of free sugar in the egg decreases equally in the white and in the yolk. On the ninth day the white is entirely deprived of free sugar, while the yolk has only lost half its original amount.

In the whole egg the amount of glycogen increases continually during incubation; in the embryo this process only takes place after the eleventh day, resulting in an actual decrease of glycogen content in the white and in the yolk after the thirteenth day. This points to the existence in the chick of a "transitory liver" possessing a glycogenetic function analogous to that of the placenta of mammals, a function which comes into play when the chick has reached half way in its development.

The total glucose of the whole egg decreases up till the seventh day, then increases until the eleventh, when it again decreases. This increase in carbohydrates between the seventh and the eleventh day corresponds to a loss of fats which do not suffer combustion but are transformed in the embryo into carbohydrates.

During the earliest stages of development the presence is determined of a large proportion of glucose, neither free nor in the form of glycogen but combined with the proteins (mucoproteins); this explains the presence in young embryos of "primitive connective tissue."

The curve of the free-sugar ratio in the embryo rises until the eleventh day, and then proceeds to fall; at this moment the glycogen ratio also undergoes a rapid change. Insulin starts to be secreted round about the tenth day of incubation.

Protein Metabolism.—There are four different kinds of protein in the albumen, according to Osborne and Campbell (1900) and others, and three different kinds of protein in the yolk of the egg, according to Plimmer and Scott (1908). During the last week of embryonic development there is a certain current of protein into the yolk and this is also true of water. Enzymes are probably contained in both albumen and yolk, according to Krukenberg (1879), Tallarico (1908) and Koga (1923), and their activity increases as incubation proceeds. The enzymes break down the proteins and prepare them for embryonic nourishment.

Fat Metabolism.—The utilization of the fat of the egg by the developing embryo has been investigated and it is apparent that fat is the most important source of energy. According to Needham (1925), the metabolism of fat takes place principally after the eleventh day. Murray (1926) determined the concentration of solid substances in the tissues of the embryo between the fifth and nineteenth days of incubation and found that the change in concentration which took place involved a relative decrease in nitrogen as compared with fat. Needham (1925) points out that the rate of the metabolism of fat is apparently controlled by the increase in the weight of the liver, which is very small up to the fourteenth day, after which it rapidly increases in size.

Utilization of Minerals.—The utilization by the embryo of the various minerals contained in the egg and in the shell has been studied by a number of workers, particularly in respect to phosphorus and calcium. The utilization of phosphorus is a very complicated problem because there are involved six different forms of phosphorus, as pointed out by Plimmer and Scott (1908). Briefly, it may be said that the greatest changes in phosphorus metabolism occur after the fifteenth day of incubation and that apparently phosphorus utilization by the embryo is associated with the calcification of bone, as discussed by Robison (1923). Concerning the utilization of calcium, Tangl (1908), Capriaux (1908), Harcourt and Fulmer (1908) and Plimmer and Lowndes (1924) all report a large increase of calcium in the embryo and a loss of it from the shell, the calcium in the shell being broken down more readily in the presence of carbon dioxide. Delezenne and Fourneau (1918) have shown that approximately 75 per cent of the calcium of the newly hatched chick comes from the shell during the process of incubation.

PHYSIOLOGICAL FACTORS RELATED TO HATCHABILITY

Not only is but little known concerning the physico-chemical changes undergone in embryonic development in general but still less is known concerning the extent to which the eggs of the same hen may vary in respect to their more important constituents and the differences that may result in the development of the embryos. A fertile field of investigational work awaits development, therefore, to determine the innate qualities of eggs from various hens as well as the innate qualities of eggs from the same hen as they may be affected by such factors as antecedent egg production, nutrition and genetic constitution.

Egg Characters and Hatchability.—Concerning various egg characters that possibly affect hatchability, Dunn (1922) has investigated the relationship between the weight and the hatching quality of White Leghorn eggs. While from among the eggs of an individual fowl those above the mean weight did not hatch so well as those below the mean weight, Dunn concluded that the effect of deviations, being so small, could not be regarded as an important cause of the variation of fowls in hatchability. Moreover, Jull and Haynes (1925) in a study of Barred Plymouth Rock eggs found no relationship between weight and hatchability. The same authors also found that egg shape, where normal eggs are involved, does not affect hatching quality. These findings corroborate those of Benjamin (1920) and Halbersleben and Mussehl (1922), who also found that color of eggs was not associated with hatchability. More recently Hays and Sumbardo (1927) failed to disclose any relationship between hatchability and the following egg characters: length, diameter, fresh weight, specific gravity, and the thickness of each the shell and the inner and outer shell membranes. Mussehl and Halbersleben (1923) found a slight correlation between specific gravity and hatchability but it was so low (0.204 ± 0.023) as to lead the authors to believe it had no practical significance. Kaupp (1924) found that eggs with normal shells hatched much better than those with thin shells and those that were ridged and mottled.

Antecedent Egg Production and Hatchability.—A number of factors of a physiological nature have been studied in respect to their effect on hatchability. Lamson and Card (1920) using White Leghorns, observed that the number of eggs laid during the 90 days previous to the hatching season did not affect hatchability. Knox (1927) also obtained no correlation between antecedent production and hatchability. Knox also found that days to maturity, date of hatch, and rate of production on the part of 92 White Plymouth Rocks did not significantly affect hatchability.

Atwood (1927) found that heavy feeding of breeding hens to induce heavy egg production prior to and during the breeding season did not adversely affect the fertility or hatchability of the eggs or the vigor of the chicks. Jull (1928*b*) found that in Barred Plymouth Rocks, Rhode Island Reds and White Leghorns egg production prior to the breeding season did not affect hatchability.

Many cases have been reported, however, where the hatchability of the eggs has been adversely affected by "forcing" pullets into excessive egg production. In cases where pullets are used as breeders, they should be given a rest prior to the hatching season, especially if they have been laying heavily.

Fertility and Hatchability.—The relationship between fertility and hatchability has been investigated by a number of workers. Pearl and Surface (1909*c*) found a small but still sensible correlation between fertility and hatchability in Barred Plymouth Rocks, while Hays and Sanborn (1924) and Jull (1928*b*) found no significant relationship between the two factors in their studies on Rhode Island Reds. Knox (1927), however, secured a correlation of 0.59 ± 0.06 between fertility and hatchability in White Plymouth Rocks. Lamson and Card (1920) observed that "the individuality of hens is the prime factor in determining the fertility of eggs from a flock." Hays and Sanborn (1924) conclude that the "fertility in the hen behaves as an individual characteristic with a fair degree of constancy from year to year." But they also found that fertility is not inherited, whereas hatchability is inherited.

Embryo Mortality and Its Causes.—Embryo mortality occurs at all times from the first to the twenty-first day of incubation, but, according to Payne (1919), over 65 per cent of the total mortality occurs at two periods of incubation, at about the fourth or fifth day and during the eighteenth and nineteenth days, the latter period being the more important. Dunn (1923*c*) found that this periodicity of embryo mortality is inherited, some lines showing a relatively high rate of mortality at the early period while other lines showed a relatively high rate at the later period.

Malformations Causing Mortality.—Sanctuary (1925) examined 1490 embryos that had died about the eighteenth day and observed 51.7 per cent to be abnormal. Nearly half of the malpositions were cases showing fully formed chicks with their heads between their thighs, thus preventing picking the shell to emerge therefrom. Sanctuary pointed out that there was some indication that the malpositions were inherited. Landauer and Dunn (1926) observed that a certain proportion of dead embryos exhibited a peculiar head formation and shortened legs. The base of the skull was found to be shortened and the upper beak protruded, giving the embryo a parrot-like appearance. The term applied to such a condition in embryos is "chondrodystrophy." The same condition has been observed by Hutt (1927–1928) and Hutt and Greenwood (1928–1929*a*), the latter of whom report that mortality caused by chondrodystrophy varied in different flocks from 0.80 to 7.96 per cent of the embryos dying after the eighth day.

Hutt (1928–1929) observed that among embryos dying after the eighteenth day, nearly 56 per cent were in one or another of the four following major malpositions: (1) the head extends downward between the thighs; (2) the head is in the small end of the egg; (3) the head is in the large end of the egg but is turned to the left instead of the right so that the beak is usually near the shell at a point directly opposite the air cell; (4) the chick lies with the head toward the large end of the egg and the beak is under the right wing as in the normal position but is rotated within the shell so that it is buried opposite the air cell.

Hutt and Greenwood (1928–1929*b*) observed that chick malformations accounted for at least 3.6 per cent of all dead embryos they examined. Harman (1929) found that small variations in temperature produce a considerable number of malformations and that variations of 5° F. produce many malformations.

Undoubtedly malformations are responsible for a goodly proportion of fully formed chicks that fail to hatch and this aspect of the subject should be investigated much more thoroughly than has been done up to the present. Aside from this, however, it is evident that causes other than malformations must be responsible for the major portion of the total embryo mortality.

Physiological Factors Causing Mortality.—Murray (1926*b*) observed that in the development of the embryo, the rates of growth and gross form development changed rapidly in the beginning, while the concentration of solids and chemical differentiation changed mostly during the last half of the incubation period. The more marked changes in form occur in the beginning when the percentage rate of growth is rapid, while there is little change in outer form later, when the increment growth rate increases. On the other hand, the most marked changes in chemical differentiation occur during the last half of the incubation period. Schmalhausen (1927) shows that growth in the chick embryo is proportional to body surface. He noted breaks in the growth curve at 4, 9, 11 and 14 days and correlated the break at 4 days with the peak in lactic acid and ammonia, the 9-day break with the peak in urea, the 11-day break with the peak in uric acid, and he suggested a correlation between the 14-day break and the shift from the mesonephros to the metanephros. The significance of these changes during embryonic development in respect to their possible influence on hatchability has hardly been investigated but such is particularly needed in view of the fact that many of the changes that occur may be due to inheritance.

The results of work conducted at the Connecticut Agricultural College (1926) led to the drawing of the following conclusions, as reported in the *Experiment Station Record* (vol. 56, No. 9, p. 869):

> During normal incubation a sudden increase in mortality beginning on the seventeenth day is noted, and about 65 per cent of the eggs hatch. When developing eggs were injected on the sixth day with 2cc. of a physiological salt solution, after an initial mortality due to the injection, there is only a slight increase in mortality in the later stages and about 50 per cent of the eggs hatch. When a small amount of lithium chloride is added to the fluid injected the reaction is the same as above up to the nineteenth day, when a high mortality occurs bringing the hatch down to 30 per cent. These results led to the belief that the cause of the late peak mortality may be sought in the early stages of incubation.

Pipping Muscle at Hatching Time.—One change occurring during the latter part of the incubation period which may be a determining factor as to whether a chick is able to emerge from the shell has been studied by Pohlman (1919), whose observations are discussed by Dunn (1924*d*).

> This is the large muscle at the back of the head of the newly hatched chick, sometimes known as the pipping muscle, although Pohlman's work has thrown doubt on the conventional view of its function. Pohlman has found that prior to the nineteenth day, it grows slowly in gross weight but that immediately thereafter it undergoes a period of sudden and rapid increase in size culminating on the twenty-first day, after which it atrophies until on the eighth day after hatching it is little more than a vestige. These changes are chiefly due to an infiltration of fluid which is more rapid into this muscle than into any other part of the chick. It must be noted that whereas the peak of embryo mortality is reached on the nineteenth day, the peak of the growth cycle of the complexus muscle does not occur until the twenty-first. We cannot infer a direct causal relation between the two events, but it is evident that individual variation in the muscle, which Pohlman says is very great, argues a more deep-seated variation in the processes which underlie its growth and these variations, we may assume, affect the success

of the embryo in hatching from the egg. We may take the growth cycle of this muscle as a typical example of a temporary or emergency growth acceleration in a single part and as a type of the important and rapid changes which take place in the chick immediately prior to hatching.

As a matter of fact, some evidence has accumulated showing that the relatively high embryo mortality occurring during the last few days of the incubation period is primarily due to causes which operate prior to the development of the complexus muscle.

Growth Rate and Mortality.—In a study of growth in weight of the chick embryo, Brody (1927*a*) shows that there is an apparent correlation between rate of growth, carbon dioxide production, and embryo mortality. From the first to the fourth days of incubation the rate of growth is constant and the increase in carbon dioxide production is of the order of 100 per cent per day. From the fourth to the fourteenth days the rate of growth is also constant and the increase in carbon dioxide production is of the order of 31 per cent per day. During the first period the growth of the embryo is at the rate of 56 per cent per day while during the second period it is at the rate of approximately 36 per cent per day.

In the data analyzed by Brody the peak in early embryo mortality occurred on the fifth day, while Payne (1919) found the peak to occur at about the fourth or fifth day. Not only is there a change in rate of growth of the embryo as well as a change in the rate of carbon-dioxide production occurring on the fifth day, but Brody points out that the peak of early embryo mortality occurring at that time represents a critical period as indicated by the presence of a peak in the concentration of lactic acid as found by Tomita (1921).

The peak of late embryo mortality occurring at about the nineteenth day, also established by Payne (1919), appears to be correlated with the pause in the percentage change in carbon-dioxide production which occurs between the sixteenth and ninteenth days. Regarding this change in rate of carbon-dioxide production, Brody (1927*b*) offers the following explanation: "The immediate threshold mechanism causing this break in the curve at this time may be the change in the mode of respiration; the function of respiration is transferred at this time from the chorioallantoic membrane to the lungs; that is, at this time the chick emerges from an aquatic to a terrestrial mode of respiration." Pembrey, Gordon, and Warren (1894–1895) have shown that the chicken embryo is not a warm-blooded animal until the very end of the incubation period.

Nutritional Factors Affecting Hatchability.—That the hatchability of eggs may be affected by the feed given the breeding stock has been demonstrated in a number of cases. Since these cases are discussed under the heading of feeding, in later chapters, only a few references are given here.

Vitamins and Hatchability.—Penquite (1925–1926) found it impossible to secure good hatches when the breeding stock was given an exclusive grain diet of white corn, either with or without green feed. White corn is deficient in vitamin A and apparently its absence in the diet of the breeders has an undesirable physiological effect on the hatchability of the eggs produced. It is well known that breeding stock having access to sunlight usually produces better hatching eggs than breeding stock that does not have access to sunlight and is not given vitamin A as a supplement to the regular diet.

The results secured by Fronda and Belo (1928) are interesting because they exposed the eggs instead of the breeding stock to sunlight. These authors concluded that sunning hatching eggs every three days during the period of incubation proved beneficial. Much along the same line, Cholevcuk (1929) found that by subjecting incubating eggs to ultraviolet rays 15 min. daily the hatchability of the eggs was increased considerably.

Green Feed and Hatchability.—Atwood (1922) found that feeding sprouted oats and green feeds in general to the breeding stock tended to give increased hatchability in the eggs.

Stuart (1929) secured results which indicated that alfalfa leaf meal and alfalfa leaves tended to improve the hatchability of the eggs laid by the birds given these feeds as compared with birds not receiving them.

Minerals and Hatchability.—Several workers have demonstrated that calcium limitation in the ration of the breeders results in thin-shelled eggs, the shells being relatively low in calcium, sometimes to such an extent that hatchability is affected. Other cases are given later in the book demonstrating that the nutrition of the breeders has an important bearing on the hatchability of the eggs they produce.

Genetic Factors Affecting Hatchability.—All of the available evidence to date concerning factors affecting hatchability points to the conclusion that hatchability is inherited and that the main hope for improving hatching results lies particularly in the field of developing strains high in the hatching power of their eggs. Dunn (1921–1922) reports that "recent studies of the causes and inheritance of variations in the hatching quality or hatchability of the eggs of the domestic fowl have indicated rather definitely that differences in the hatchability of eggs are determined by innate differences in the individual hens which lay them," and "that these differences are probably inherited." Pearl and Surface (1909*c*) were the first to demonstrate that hatchability is inherited and Hays and Sanborn (1924) confirmed this observation and have demonstrated in their breeding work with Rhode Island Reds at the Massachusetts Agricultural Experiment Station that selection for high hatchability with the female as a guide and using cockerels from hens that hatched well has been a slow but progressive process. Hays (1926) secured results which led him to conclude that the male is an important factor in hatchability.

Inbreeding and Outbreeding and Mortality.—Cole and Halpin (1916) and Dunn (1923*c*) secured evidence showing that close inbreeding increases the total rate of embryo mortality. Pearl and Surface (1910*c*) crossed Barred Plymouth Rocks with Cornish and observed an increase in hatchability over that of each breed. Warren (1927) obtained similar results in a cross between White Leghorns and Jersey Black Giants. Jull (1929*c*) inbred Barred Plymouth Rocks and White Leghorns and observed that hatchability decreased each succeeding year that inbreeding was continued but that when different varieties of Plymouth Rocks were crossed hatchability was increased. The results of these investigations are given in Chap. X.

A Lethal Gene.—Dunn (1923*g*) determined the existence of a lethal gene, causing the death of embryos, which is inherited in a Mendelian manner.

Improvement through Breeding.—These and other genetic factors involved in hatchability are cited by Dunn (1924*d*), from which it may be concluded fairly definitely that the problem of improving hatchability is largely a problem of breeding, assuming that the breeding stock is fed so-called "normal" rations.

CHAPTER XIII

INCUBATION PRINCIPLES

The domestic hen of today incubates its egg in precisely the same manner as the wild fowl of the bamboo jungles of India and Ceylon has incubated its eggs for many centuries. The modern incubator, however, incubates eggs in a very different manner from that employed by the Egyptians and Chinese in their mud ovens and barrels during at least the past several thousand years.

Ancient Methods of Incubation.—In contrast with the rather remarkable changes that have taken place during recent years in the development of the type of incubator for hatching chicks commercially in America it seems strange that the methods of incubation used in the earliest times in Egypt and China are still in use there. The immense Egyptian hatching ovens, called *mamel el firakh*, constructed of sun-dried brick, mortar and earth, usually have several compartments, each capable of holding a few thousand eggs.

The eggs are brought from many miles around the hatching oven on the backs of asses and camels. Heat is furnished by fires built in the rooms where the eggs are hatched, as shown in Fig. 56, the proper temperature being maintained by the use of ventilators in the walls. The fuel is usually wheat or bean straw chopped and mixed with a certain amount of camel dung, or "gilch." No thermometer is used, since the attendant tests the temperature of the eggs by the touch of the hand or by placing them against the eyelid. The eggs are placed in the lower chambers and are often piled up four or five deep, but not later than the tenth day are spread out in a single layer.

The eggs are turned three times daily. On the fourth or fifth day they are tested for fertility, the infertile eggs being removed and sold for human consumption. The testing is usually done in the upper chambers, each egg being held in a ray of sunlight which comes through a hole in the roof made for the purpose. No artificial moisture is provided and no special provisions are made for securing fresh air. Further details concerning the description and methods of operating the Egyptian hatching ovens cannot be given here but those who wish to pursue the matter further should consult Crouch (1683), Reaumur (1750), Aldrich (1912), Cadman (1912) and Jeffreys (1913).

The incubation methods of the Chinese are just as primitive as those of the Egyptians but their incubators are different. There are three types of Chinese incubators: mud-plastered, straw-covered and muslin-covered barrels, the mud-plastered barrels being shown in Fig. 57.

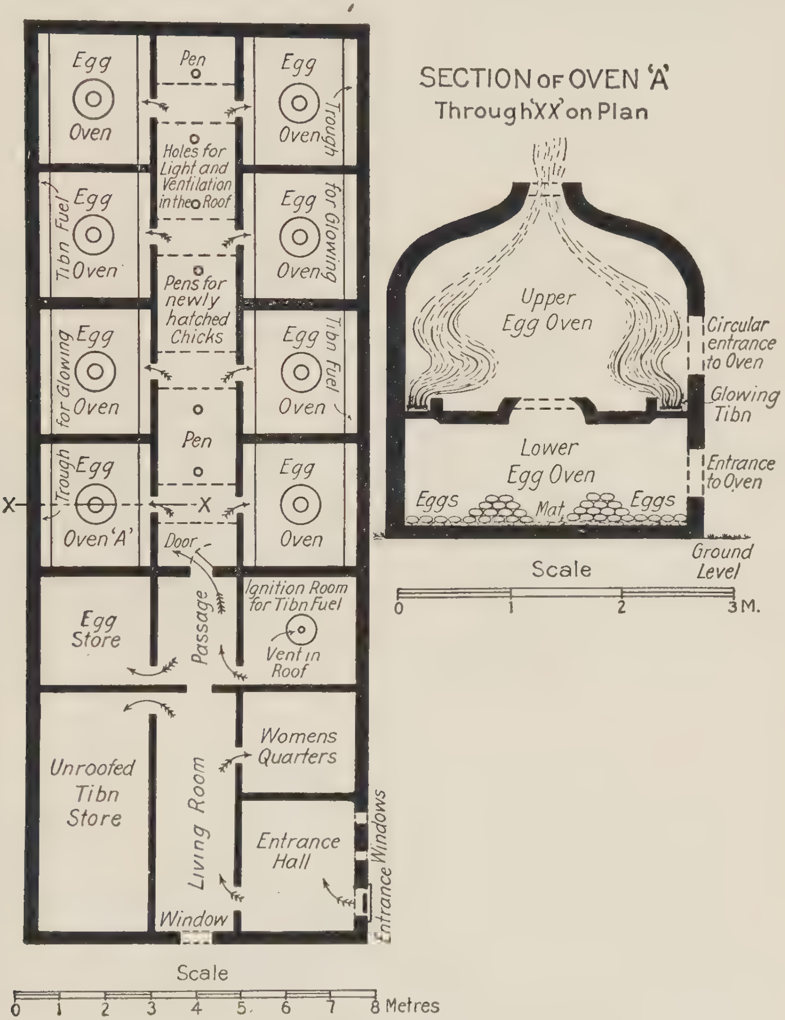
Egg Oven
Pen
Egg Oven
Trough for Glowing Tibn fuel
Holes for Light and Ventilation in the Roof
Tibn Fuel Egg Oven
Egg Oven
Pens for newly hatched Chicks
for Glowing Egg Oven
Egg Oven
Pen
Trough Egg Oven 'A'
Egg Oven
X
X
Door
Egg Store
Passage
Ignition Room for Tibn Fuel
Vent in Roof
Unroofed Tibn Store
Living Room
Womens Quarters
Entrance Hall
Windows
Entrance
Window
Scale
0 1 2 3 4 5 6 7 8 Metres
SECTION OF OVEN 'A'
Through 'XX' on Plan
Upper Egg Oven
Circular entrance to Oven
Glowing Tibn
Lower Egg Oven
Entrance to Oven
Eggs
Mat
Eggs
Ground Level
Scale
0 1 2 3 M.

FIG. 56.—Egyptian hatching ovens are usually built of mud walls with circular openings to allow people to enter and to provide sufficient ventilation. The attendant frequently lives in one of the rooms of the oven and is extremely sensitive to changes in temperature. There is a dome-shaped roof with holes for smoke to escape.

Many of the ovens are composed of compartments, each compartment being divided into an upper and lower chamber. The eggs are placed on the floor of the lower chamber and are turned frequently. The fires are built around the walls of the upper chamber. (*Plan by Illustrated Poultry Record.*)

Their general use is governed by locality; in the country and village districts, where straw and mud are easily accessible, the first two types are preferred while in the towns and cities the muslin-covered incubator is preferred. Notwithstanding the differences in construction, the method of heating each of the three incubators is practically the same, the heat being supplied by burning charcoal or by placing the incubators in piles of decomposing manure. As with the Egyptians, so with the Chinese, the thermometer used in the modern incubator is almost totally unknown. A slight variation in the temperature is detected by placing a few eggs against the eyelid.

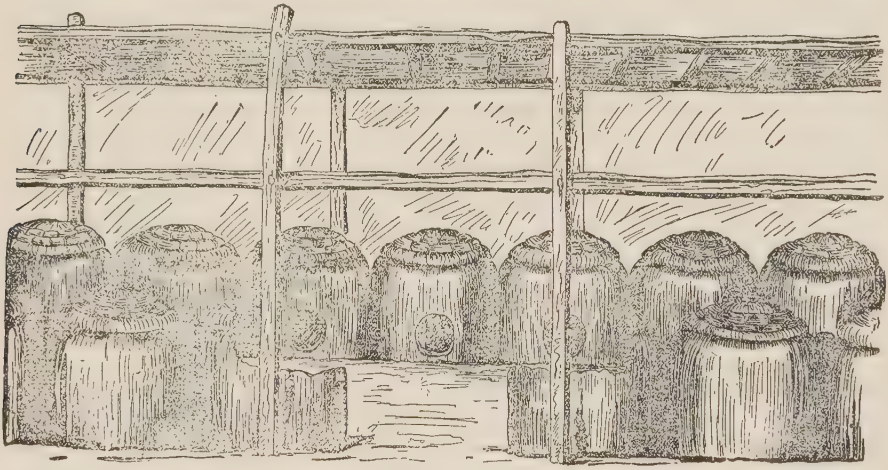

Fig. 57.—Showing the arrangement of Chinese incubators. (*From Brill, U. S. Dept. Agr.*)

The capacity of each incubator varies from about 400 to about 1,500 eggs. The eggs are turned three or four times daily. As early as the fourth day they are tested for fertility, the infertile ones being removed and sold. Throughout the entire period of incubation no moisture is used, although the hatches are reputed to be highly successful. In some cases provision is made for ventilation by having holes in the top of the incubator, a varying number of which may be opened as required. Chinese incubators have been described by Brill (1900), King (1911) and Chung (1918).

Early European Incubators.—In Europe many attempts were made to incubate eggs artificially before any degree of success was attained. As early as 1580, Porta, an Italian physician, constructed an incubator in which warm air was utilized. Reaumur (1750) published his observations on artificial incubation, his experience proving that eggs could be incubated successfully by specially constructed heating devices. Several years later Huzard, according to Bouges (1923), constructed an incubator of complicated design to hold as many as 6,000 eggs. According to the same author, Bonnemain in 1777 and Foncault in the same year practiced artificial incubation successfully. About 1850 Séguier devised an apparatus for supplying heat to the eggs by means of a sack of "caoutchouc" filled with warm water, the sack lying on top of the eggs. Roullier-Arnoult (1880), Gobin (1882) and Dareste (1891) published their

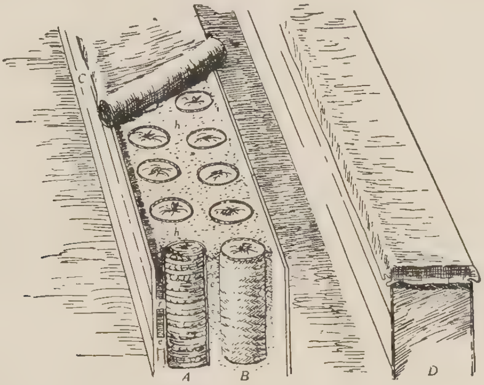

Fig. 58.—A diagrammatic sketch of a hatchery in Pateros the Philippines. *A*, *B* and *D*, are rows of incubators (cylindrical baskets) in which *A* shows the basket in section to give an idea of the arrangement of the bags containing the egg to be incubated and those containing heated rice, *B* shows the entire basket and *D* shows the row of baskets covered. This is also shown in *C*, but only partly rolled. *e*. Bags containing eggs. *r*. Bags of heated rice. *h*. Rice hulls firmly tamped and serving as insulators. (*Fronda*, 1925–1926.)

results on artificial incubation. Kaester (1895) used much the same methods as employed by Séguier.

Modern Incubators.—The earliest of modern incubators appeared in England in 1770 and in America in 1844. The chief difficulty encountered in the operation of these early incubators was in respect to maintaining a satisfactory temperature for successful incubation. It was not long, however, before mechanical devices for controlling the temperature

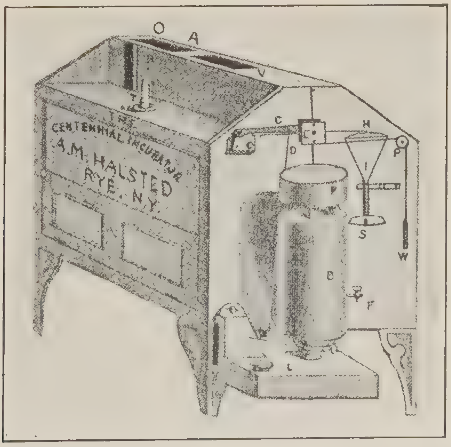

Fig. 59.—One of the earliest incubators in practical use in the United States. (*Photograph by Everybodys Poultry Magazine.*)

were perfected to such an extent that the temperature throughout the twenty-one days of incubation could be controlled within a degree Fahrenheit variation from day to day. This was possible in spite of the fact that the developing embryos give off considerable heat during the latter part of the hatch. As far as temperature control in modern incubators is concerned, therefore, it has become a problem of determining optimum temperatures for the entire period of incubation.

Factors Affecting Hatching Results.—Physical factors of greatest importance in the incubation of eggs include temperature, humidity and ventilation. A review of the literature indicates that conditions of incubation are of great importance in determining the percentage of chicks that hatch from a given number of eggs but that conditions may vary within certain limits without seriously affecting results. This is true in natural as well as in artificial incubation.

The Problem of Temperature.—That temperature was the first physical factor in incubation to receive consideration is easily understood when it was found that normal embryo development can only take place within certain narrow limits of temperature. For the most part the early investigational work on proper temperatures in artificial incubation was based on the observations of temperatures recorded under conditions of natural incubation.

Temperature under Hens.—Eycleshymer (1907) recorded the daily temperature of four setting hens with the thermometer in contact with the bodies of the hens and found that it tended to rise slightly during the first week of incubation, after which it remained fairly constant. On the first day the temperature among the four hens ranged from 101.5 to 103.0° F. while on the seventh day the surface temperature of two hens was at 104.5° F. and that of the other two was at 105.0° F. From the eighth to the twentieth day the daily temperatures ranged from about 104.0 to about 105.5° F. Cadman (1923) observed that the nest temperature of setting hens remained fairly constantly at 104.5° F. throughout the period of incubation.

Eycleshymer (1907) observed that the daily temperature of the eggs under the setting hen was from about 3.5 to 1.5° F. lower than that of the hen, the greater differences occurring during the earlier period of incubation. In other words, while the surface temperature of the hen increased slightly during the first week and thereafter remained fairly constant, the temperature of the eggs increased steadily throughout the entire period of incubation. This observation was confirmed by Simpson (1911, 1912).

Temperature Variations in Natural Incubation.—Cadman (1923) made observations on the daily temperatures at the top and the bottom of the eggs as they lay in the nest under the setting hen and found that during the fore part of the incubation period the top temperature was about 18.0° F. higher than the bottom temperature, but that the difference lessened as the incubation period progressed Atkinson (1924) made similar observations. Burke (1925) found, from hourly readings taken between 5 a.m. and 9 p.m., that the difference between the top and bottom temperatures of eggs under a setting hen was approximately from 15.0 to 18.0° F. during the first few days and about 11.0° F. during the last few days of the incubation period. The average range in temperature at the top and the bottom of the egg as observed by Burke, using five hens, is shown in Table 33 and Fig. 60.

TABLE 33.—THE AVERAGE TEMPERATURE OF THE TOP AND BOTTOM OF THE EGG UNDER NATURAL CONDITIONS OF INCUBATION

(Burke, 1925)

Day of incubation	Average daily temperature	
	Top of egg, ° F.	Bottom of egg, ° F.
1	100.3	85.2
2	102.5	86.4
3	102.7	86.4
4	102.1	86.8
5	102.7	88.6
6	102.6	89.7
7	102.2	89.9
8	102.3	89.4
9	102.1	88.9
10	102.3	88.7
11	102.5	88.9
12	102.1	89.9
13	102.3	91.5
14	102.4	92.8
15	102.1	92.3
16	102.3	92.1
17	102.3	90.7
18	102.1	90.7
19	102.5	90.6
20	102.5	89.4
21	103.5	94.1

It will be observed from Burke's data that, whereas the daily temperature at the top of the egg remained fairly constant, the temperature at the bottom of the egg increased perceptibly up to about the sixteenth day, after which it decreased until the twentieth day. Eycleshymer (1907) and Simpson (1911) both observed, however, that the temperature of the egg in the nest increased steadily, though only slightly, throughout the incubation period. The apparent difference between the trend of the temperature of the egg as observed by Eycleshymer and Simpson on the one hand and Burke on the other may have been due to the fact the thermometers were not placed in the same relative positions for obtaining the temperature of the egg. Eycleshymer and Simpson may have placed the bulb of the thermometer at approximately the center of the egg, in which case their observations would be in keeping with those of Burke. In respect to the temperature at the bottom of the egg, Cadman (1923) observed the same trend as that observed by Burke.

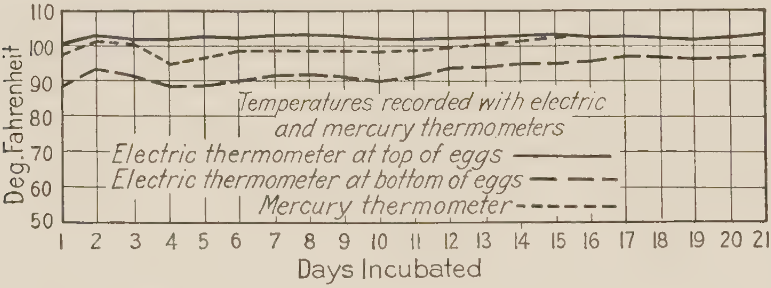

FIG. 60.—The average range in temperature at the top and at the bottom of eggs incubated in an incubator. (*After Burke*, 1925.)

The more general conclusions to be drawn from the observations made by the various investigators are: (1) the surface temperature of setting hens rises about 3.0° F. during the first week of incubation and remains fairly constant thereafter; (2) the temperature of the nest tends to increase slightly and steadily during the incubation period; (3) the temperature at the top of the egg tends to remain fairly constant during the incubation period; (4) the temperature at the bottom of the egg is approximately from 15.0 to 18.0° F. lower than the temperature of the top of the egg at the beginning of the incubation period but this difference decreases as incubation proceeds, so that toward the end of the incubation period the temperature at the bottom of the egg is approximately from 9.0 to 13.0° F. lower than the temperature of the top of the egg; (5) the temperature at the bottom of the egg tends to rise by probably from 6.0 to 9.0° F. from the first to the sixteenth days and then falls about 2.0° F. from the seventeenth to the twentieth days.

The various observations made concerning temperature conditions under natural methods of incubation are of particular value in respect to their possible application to artificial incubation. Incubators of many different types have been devised so that it has become necessary to determine optimum temperatures for incubation purposes in the different types.

Types of Incubators.—Incubators may be divided into three groups according to the method employed in supplying heat to the eggs in the egg chamber.

The first group comprises the "hot-air" and "hot-water" classes of incubators. In the case of hot-air incubators, the warm air is conducted into the top of the egg chamber and diffuses downward over the eggs, while in the case of hot-water incubators, one of which is shown in Fig. 61, the eggs are heated by radiation from the heat supplied to the reservoir or pipes of water in the upper part of the egg chamber. The incubators of this group vary in size from small machines holding about fifty eggs in one compartment to mammoth machines holding several thousand eggs. The mammoth machines, however, consist simply of a large number of compartments placed end to end and there may be one, two, or three tiers of them, the compartments being independent of each other. In the first group of incubators heat is supplied by burning coal oil, gas or coal, or electricity may be used.

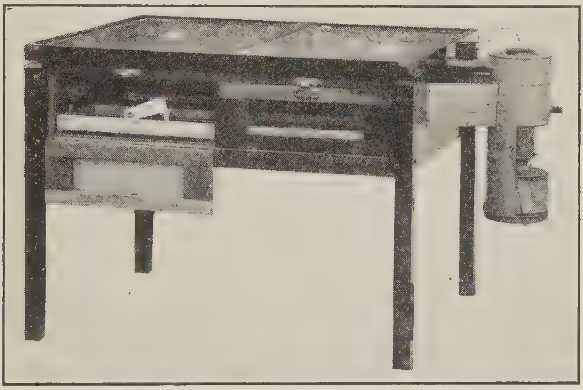

FIG. 61.—A typical lamp incubator, heated with kerosene. (*Photograph by Queen Incubator Co.*)

The second group comprises those makes of incubators in which currents of air pass over heated water pipes and then by means of electric fans the warm air currents are forced through the air chamber. The incubators of this group, one of which is illustrated in Fig. 62, are commonly spoken of as "cabinet-type" machines and are compact in design. The eggs are placed on trays which are in tiers one above the other. There is a forced circulation of warm air from the bottom of the egg chamber to the top. Heat is supplied by burning coal oil or gas, or electricity may be used, in which case heating elements displace the water pipes as a means of supplying heat.

The third group of incubators is that in which heat is supplied by means of electric heating elements placed in the bottom of the machine, which is of the cabinet-type design, and a uniform temperature is obtained by stirring the air by means of a baffler or wheel paddle (see Fig. 66). The use of electricity in incubation is discussed by Dougherty (1929) and Garver and Carver (1929).

Temperature in Incubators.—The proper temperature for successful incubation varies considerably for the incubators of the different groups, as would be expected where the heat is distributed in a different manner in each group. In the second and third groups of incubators the optimum temperature is quite different from that in all classes of incubators belonging to the first group. It is only with the incubators of the first group that much experimental work has been conducted independent of the valuable work done by the incubator manufacturers. The various results discussed below have to do entirely with the incubators of the first group.

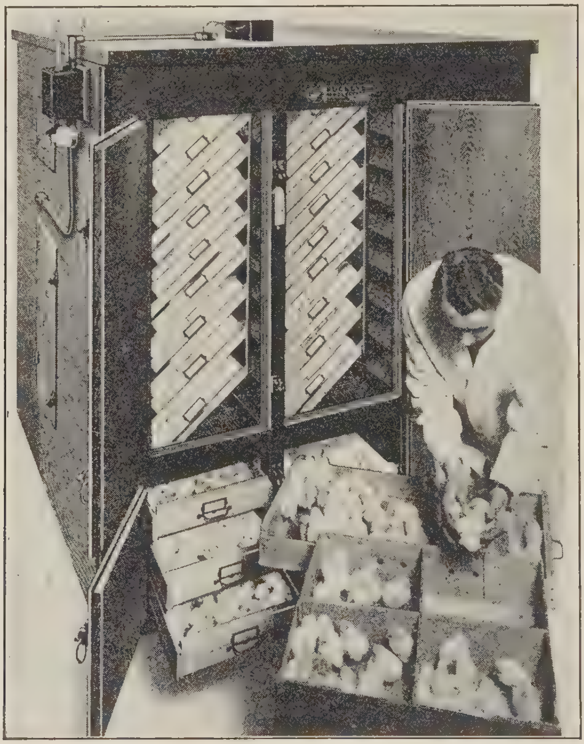

Fig. 62.—A mammoth-type incubator operated entirely by electricity. (*Photograph by Buckeye Incubator Co.*)

Eycleshymer (1907) observed that the temperature taken on a level with the top of the eggs as they lay on the tray in the compartment of the incubator, the bulb of the thermometer not being in contact with any egg, was approximately from 2.0 to 3.0° F. lower than the temperature of the incubator chamber, the latter temperature presumably having been taken a few inches above the top of the eggs. Eycleshymer came to the conclusion that the best temperatures are approximately from 102.0 to

103.0° F. during the first half of the incubating period and approximately 103.0 to 104.0° F. during the last half, these temperatures being maintained on a level with the top of the eggs but with the bulb of the thermometer not in contact with any egg.

Covalt (1912) observed that during the first 18 days the temperature on a level with the top of the eggs should be 103.0° F., after which the thermometer should be suspended in the egg chamber about ½ in. above the eggs and the temperature should be 103.5 to 104.0° F. Dougherty (1915) concluded that 102.0° F. was the best temperature to be maintained on a level with the top of the eggs, the bulb of the thermometer touching a fertile egg. Atwood (1917), in an excellent review of various incubation problems, suggests that for the first week the thermometer should rest on the top of the eggs and a temperature of 102.0° F. should be maintained, and then the thermometer should be suspended ½ in. above the eggs and should register a temperature of 102.5° F. for the rest of the incubation period.

Philips (1916*a*, 1917) observed that when the bulb of the thermometer was approximately 1½ in. above the bottom of the egg tray the temperature during the first, second and third weeks should be 101.0, 102.0 and 103.0° F., respectively, although it was later observed, Philips and Brooks (1923), that a relatively constant temperature of 101.0° F. throughout the entire period of incubation gave better results. The observations of Philips seem to be more in keeping with the observations made by Eycleshymer, Covalt, Dougherty and Atwood than those of Philips and Brooks, and, if conditions of incubation were entirely uniform as between Philip's and Philips and Brooks' experiments, the different observations they made are difficult to explain.

It has been pointed out previously that Cadman (1923), Atkinson (1924) and Burke (1925) found that the temperature at the top of the egg in natural incubation was considerably higher than the temperature at the bottom of the egg. Atkinson (1924) investigated the matter with respect to artificial incubation and found that there was a difference of 4.0 to 5.0° F. between the top and bottom temperatures of the egg in the type of incubators on which the previous results have been discussed, whereas in incubators in which there is a forced circulation of air there was no difference between the top and bottom temperatures. Based on his observations under natural methods of incubation, Atkinson endeavored to apply the same principle in artificial incubation. He covered the eggs in the incubator with a very thin sheet of India rubber and secured much better hatches, although there is a paucity of data.

Burke (1925) observed a difference of approximately 4° F. between the temperature at about one-half inch above the eggs and on a level with the top of the eggs in a hot-air incubator during the fore part of the hatch, the difference decreasing as incubation progressed, as shown in

Fig. 63. The general conclusion which Burke arrived at is that for the first two weeks the temperature on a level with the top of the eggs should be 102.5° F. and for the third week, not over 103.0° F., with a temperature of 104.0 to 106.0° F. while the chicks are hatching. Moreover, Burke concluded that proper temperature is the most important factor in incubation.

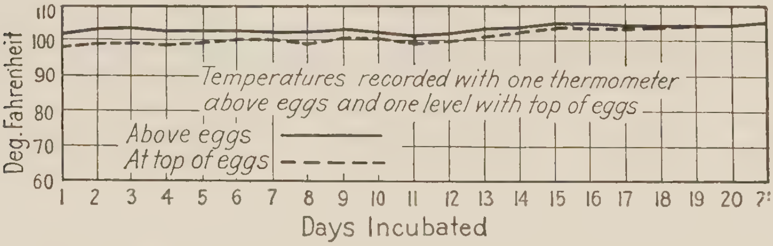

FIG. 63.—The average range in temperature at ½ in. above eggs and at top of eggs incubated in an incubator. (*After Burke*, 1925.)

The Problem of Humidity.—During incubation the egg loses weight, part of which is due to loss in water content, as explained on page 174. If too much water is lost from the egg during incubation, the results in hatching are usually seriously affected. Eggs incubated artificially readily lose too much moisture if corrective measures are not provided.

Loss of Water.—The general results of Gilbert (1894), Graham (1906), Eycleshymer (1907), Laurie (1911) and Atwood (1901) show that fertile eggs under natural conditions of incubation lose approximately 10 to 17 per cent of their original weight, depending largely upon the kind of nest in which the eggs are incubated. It must be remembered, of course, that the developing embryos give off carbon dioxide and absorb oxygen in progressively increasing quantities as incubation proceeds. Loss in weight of the eggs, therefore, is not due entirely to evaporation of the water content though this is the principal contributing factor.

In artificial incubation Graham (1906) found that the eggs lost from about 9 to 16 per cent of their original weight. Eycleshymer (1907) believed that the humidity of the egg chamber should be controlled so that the eggs would not lose more than approximately 13 per cent of their original weight. Dryden (1907, 1908), Graham et al. (1908), Jeffrey (1909), Servis (1911*a*) and Lewis and Clark (1913) demonstrated that the addition of moisture to the egg chamber resulted in increasing hatchability. Atwood (1901) published a table showing the normal loss in weight per 100 eggs under what he believed to be optimum humidity conditions.

Optimum Humidity.—What is of particular interest to operators of incubators however is to know the optimum humidity in order to obtain most satisfactory results in incubation. The weighing of eggs to determine if they have lost sufficient moisture is hardly practical and the results of Lamson and Kirkpatrick (1918) would seem to indicate that such is not necessary. An extensive series of experiments on hatchability in relation to relative humidity gave the results shown in Table 34.

TABLE 34.—RELATION OF RELATIVE HUMIDITY TO THE LOSS IN WEIGHT OF EGGS DURING INCUBATION AND TO HATCHABILITY. THE AVERAGE INITIAL WEIGHT OF THE EGGS WAS 57 G.

(Lamson and Kirkpatrick, 1918)

Relative humidity	Average loss in weight per egg, grams	Per cent loss in weight	Per cent of fertile eggs hatched
0.70 to 0.80	3.03	5.3	45.5
0.60 to 0.70	4.96	8.7	62.1
0.50 to 0.60	5.61	9.8	69.3
0.40 to 0.50	5.82	10.2	68.6
0.30 to 0.40	6.57	11.5	68.6
0.20 to 0.30	8.29	14.5	60.6
0.15 to 0.20	9.94	17.4	48.0

Palmer and Dykes (1926) secured hatching results as influenced by the relative humidity of the air in the incubator as shown in Table 35, the work having been in Alberta, Canada, a normally dry section of the country.

TABLE 35.—PER CENT OF FERTILE EGGS HATCHED IN RELATION TO THE RELATIVE HUMIDITY OF THE AIR IN THE INCUBATOR

(Palmer and Dykes, 1926)

Variety	Month	Relative humidity of incubator air	Per cent of fertile eggs hatched
Barred Plymouth Rock.................	February	54.5	74.4
		32.8	43.7
Barred Plymouth Rock.................	March	56.0	78.9
		33.2	42.5
Barred Plymouth Rock.................	April	60.1	85.8
		35.0	45.4
Single-comb White Leghorn.............	May	67.0	97.0
		53.5	79.5

From the data shown in Tables 34 and 35 it is apparent that the air of the egg chamber should have a relative humidity of about 60 per cent. A wide latitude is possible, depending upon the section of the country, although Murray (1925*b*) adopted a relative humidity of 67.5

per cent and a temperature of 102.0° F. as the standard in conducting a series of incubation experiments on physiological problems.

Atwood (1901), Lamson and Kirkpatrick (1918) and Murray (1925*b*) all believe that it is the relative rather than the absolute humidity of the air in the egg chamber that is of greater importance.

The Problem of Ventilation.—It has been pointed out previously that as the embryo develops during incubation carbon dioxide is given off and oxygen is required in increasing quantities. Ventilation requirements in the incubator satisfactory for the normal development of the embryo during the fore part of the incubation period may not be satisfactory for normal development during the latter part of the incubation period.

Adequate Ventilation Necessary.—That lack of proper ventilation may adversely affect results has been demonstrated by Eycleshymer (1907), who hatched 85.7 per cent of the fertile eggs in an incubator given special ventilation and only 44.3 per cent of the fertile eggs in an incubator not given any ventilation. Graham (1908) observed that when the lamp fumes from the incubator lamp were introduced into the egg

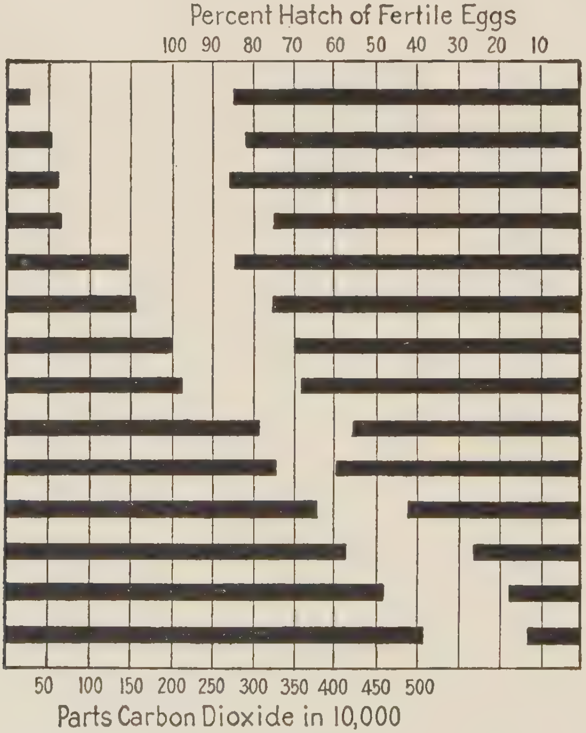

Fig. 64.—The effect of carbon dioxide upon the per cent of fertile eggs hatched. (*Lamson and Kirkpatrick*, 1918.)

chamber, for the purpose of increasing the carbon dioxide content, hatchability was adversely affected, though the chicks which did hatch were quite strong.

Excesssive Carbon Dioxide Harmful.—A number of workers, Brigham (1901), Dryden (1907), Edmond (1907), Thom (1908), Atwood and Weakley (1915), determined the amount of carbon dioxide in the atmosphere of the egg chamber and under setting hens during incubation and found for the most part that about 30 in 10,000 parts of air represented the maximum reached under normal conditions of incubation whereas under setting hens the amount of carbon dioxide attains a maximum of about 50 in 10,000 parts of air. It does not appear, therefore, that in artificial incubation there is any danger of an excess of carbon dioxide accumulating in the egg chamber. This observation is supported by the results secured by Szuman (1926).

Lamson and Edmond (1914) investigated the matter further, however, and found that if the carbon dioxide content of the egg chamber reached as high as about 100 in 10,000 parts of air no marked deleterious effects on hatchability were noticeable. The results of their investigations are shown in Fig. 64. Rogalski (1925) has shown that excessive amounts of carbon dioxide inhibit the development of the embryo and cause lesions. The longer the exposure of the embryo to carbon dioxide and the higher the temperature under which the carbon dioxide acts, the more extensive the lesions. Atwood and Weakley (1924) suggest that since the amount of carbon dioxide given off by the embryos increases considerably during the last few days of the incubation period, the amount of air passing through the incubator should be increased accordingly.

CHAPTER XIV

INCUBATION PRACTICE

When it is realized that more than 150,000,000 laying pullets have to be raised in the United States annually to replace more than one-third of the 400,000,000 hens estimated to be the country's annual poultry population, it becomes apparent that the adoption of the most efficient methods of incubation is of the greatest practical importance.

The fundamental object of incubation is to obtain the largest possible number of good chicks in porportion to the number of eggs set. The problem of successful incubation, therefore, is an important one, because inefficient management during incubation spoils hatching eggs of good quality which would normally hatch into good, strong chicks.

Fig. 65.—The thorough cleaning and disinfection of the incubator after each hatch is completed is a fundamental principle of successful incubation operation. (*Photograph by Buckeye Incubator Co.*)

Advantages of Incubators.—Incubators should be used if early chicks or large numbers of chicks are required. Many of the flocks of the country are composed of Leghorns, a non-setting breed, so that incubators have to be used. In other breeds that are bred for egg production broody hens are sometimes scarce when the eggs should be incubated. There are many sections of the country where the use of an incubator and coal-burning brooder would enable the farmer to hatch and rear chicks in time to have them develop into October and November layers. The use of an incubator offers many advantages over setting hens in spite of the fact that among early investigations, Dryden (1908, 1909, 1916), Graham (1908) and Gilbert (1909, 1911), better hatches were usually secured under natural than under artificial methods of incubation.

Sanitation in Incubation.—Proper sanitation in incubation can not be overemphasized, because lack of sanitation may be the cause of poor hatches and high mortality in the chicks. The eggs should be clean, because dirt on the shells may harbor disease organisms. If natural incubation is practised, the setting hens should be treated with sodium fluoride to rid them of lice, and the nests should be kept clean and free from lice and mites. Incubators should be cleaned before placing the eggs in them. Disinfect the interior of the machine as well as the egg trays and nursery drawers with an efficient disinfectant, such as a saponified cresol solution.

Time to Hatch.—The time that chicks are hatched has a more important bearing on the economic returns made from the flock than most poultrymen realize. Vickers and Cray (1925) report that in the case of 150 farm flocks in Ohio the pullets which were hatched before the first of May laid an average of 152.9 eggs each, while the pullets which were hatched after the first of May laid an average of 143.4 eggs each in their first year of production. Upp and Thompson (1927) show that in Oklahoma pullets hatched not later than the first week in April lay much better during the first year of production than those hatched after the first week in April. Berry and Walker (1927) found that pullets hatched in April in New Mexico laid better than those hatched either in March or May or any other month of the year.

Goodale (1918*d*) has shown, in the case of Rhode Island Reds at the Massachusetts Agricultural Experiment Station, that pullets hatched in March gave an average winter production of 42.65 eggs per bird, those hatched in April 35.40 and those hatched in May 22.50 eggs per bird. Card (1917*a*) concluded that in Connecticut Leghorns should be hatched during late April or early May. Lewis (1921) showed that in New Jersey Leghorns hatched in April grew much faster than those hatched in June.

Jull and Lee (1928) make the following observations:

> Leghorn pullets and those of similar breeds should come into laying when about six months old, and the heavier breeds, such as Plymouth Rocks, Rhode Island Reds and Wyandottes, should begin laying when about seven months old. Therefore, in order to take advantage of the high egg prices during the fall and winter months, pullets should be hatched about six months prior to the middle of October, in the case of Leghorns, and about seven months prior to the middle of October, in the case of the heavier breeds. In the southern sections of the country the growing season is much longer than in the northern sections, and it has been found that chicks hatched after the middle of April in the South frequently do not do well. In the South, therefore, Leghorn chicks should be hatched by the first of April and those of the heavier breeds by the middle of April, while in the North, Leghorn pullets may be hatched up to the fore part of May, and those of the heavier breeds may be hatched up to the middle of April.
>
> These dates, of course, are only approximate; the important thing is that farmers should hatch their chicks early if the highest profits are to be made in egg production the following year. It has been demonstrated repeatedly that late-hatched chicks do not do so well as early-hatched ones.

There are advantages from hatching early other than those given above. In the case of early hatched chicks the males may be sold as broilers early in the season, when prices are usually highest. For instance, when chicks are hatched about the middle of April the males may be separated about the middle of July and sold as broilers when the price is usually very good, owing to the fact that other kinds of fresh poultry meat are scarce. Still another advantage of hatching chicks early is that early fryers are for sale before the great bulk of the poultry goes on to the market in the fall, and also one may have well-matured roasters ready for the Thanksgiving market.

Number of Eggs to Set.—The number of eggs that should be set is determined by the number of matured pullets required. Under ordinary circumstances a hatch of at least 60 per cent of all eggs set is a reasonable expectation and one should expect to raise to maturity at least 80 per cent of the chicks hatched. For every 100 eggs set, therefore, there should be raised at least 50 matured chickens, of which approximately one-half would be cockerels. For every 25 select laying pullets required approximately 120 eggs should be set. Philips (1916*b*), in the case of White Leghorns, found that it was necessary to set an average of 4.57 eggs to raise a pullet to 24 weeks of age.

The careful selection of the breeding stock is of prime importance in effecting hatchability; the more carefully the breeding stock is selected the fewer eggs required to be set. Lamson and Card (1920) found that in a group of 341 hens 181 eggs were required to produce 100 chicks; in the case of 108 selected hens from the entire group 146 eggs were required to produce 100 chicks; and in the case of a group of 67 of the best hens in the entire group only 126 eggs were required to produce 100 chicks.

Selecting and Holding Hatching Eggs.—The careful selection of eggs for hatching purposes is a very important matter because the kind of egg incubated determines, to a large extent, the quality of chicks hatched. Fertile eggs of good hatching quality are necessary for good hatches. All eggs for hatching should be uniform in shape and size and sound in shell.

Egg Size Important.—The size of the eggs used for hatching is very important because there is a high correlation between the size of eggs used and the size of chicks hatched, as observed by Benjamin (1920), Halbersleben and Mussehl (1922), Jull and Quinn (1925) and Upp (1928). Furthermore, the continued use of small eggs for hatching purposes would soon result in the depletion of the constitutional vigor of the laying or breeding stock, as well as decrease in the size of eggs shipped to market. The most careful attention, therefore, should be given to the selection of the eggs for hatching purposes on the basis of size, and it is desirable to use no eggs weighing less than 2 oz. each.

Shell Color Important.—In the case of varieties of chickens that lay white-shelled eggs, all eggs used for incubation should be free from tints.

Punnett (1923) has discussed the question of the inheritance of egg color and has demonstrated that only by continuous selection of the breeders can the production of tinted eggs, be eliminated from the flock. This is an economic factor which has caused trouble in some strains of White Leghorns. In shipping eggs to market there is a tendency for the trade to discriminate against white eggs having tinted ones mixed with them.

Test for Cracked Shells.—All eggs should be tested for cracked shells, which can be done quite readily by tapping two eggs together. If there is a resonant sound, both eggs are sound in shell; but if there is a dull sound, one of the eggs is cracked and should not be used for incubation.

Avoid Dirty Eggs.—Dirty eggs should not be washed because washing opens the pores and makes possible excessive evaporation of the watery content during incubation. If dirt is observed on the shell, scrape it off with a knife, or reject the egg.

Use Fresh Eggs Only.—Only fresh eggs should be set because eggs for incubation deteriorate rather quickly after they are about 5 days old while eggs 3 weeks old or more, usually do not hatch at all. Broca (1862) and de Lavison (1862) demonstrated that when eggs were held as long as 27 days their hatchability decreased materially. Dareste (1883) found that the longer eggs were held before being incubated the greater was the percentage of abnormal chicks among those hatched. Philips (1909) secured low hatchability from eggs kept over two weeks. Lamson and Kirkpatrick (1918), using Rhode Island Red eggs, secured a hatch of 71.1 per cent of all fertile eggs set in eggs from 3 to 5 days old and a hatch of 63.5 per cent in eggs 11 and 12 days old. Waite (1919) found that when eggs were held over 10 days their hatchability decreased below 50 per cent. It is apparent, therefore, that eggs should not be held over 10 days and the fresher they are the better. If the incubator capacity is relatively large and a large number of eggs have to be saved before setting time they should be kept in a cool room free from drafts and dust.

Position Not Important.—From the results of various investigations, Gowell (1902) and Jackson (1912), it is apparent that there are no advantages in keeping eggs in any particular position while being held for incubation, provided they are not kept over ten days. They may be kept in a tray in their natural position and, according to Jackson (1912), do not require to be turned.

Avoid High Temperature.—The temperature at which eggs are held prior to being incubated is quite important, a high temperature being more injurious than a low temperature. Philips (1909) observed that eggs held at a temperature of 50.0° F. hatched much better than those held at a temperature of 65.0° F., while eggs held at 80.0° F. failed to hatch. That a temperature of 80.0° F. is excessive is borne out by the observation of Edwards (1902) to the effect that the embryo may begin to develop at about 68.0° F. Although Mauro (1923) failed to observe any embryonic development in eggs kept for ten days at 32.9° F., others kept at 57.2° F. showed development in 60 per cent of the eggs.

Just how low the temperature may be allowed to go without endangering embryonic development has not been determined. Elford (1921) packed eggs as for shipment and kept them at a temperature of from 14.0° to 26.0° F. for five hours and secured a hatch of 80 per cent of the fertile eggs. Musschl and Bancroft (1924–1925) found that when eggs were held for six hours at 32.0° F. hatchability was apparently not impaired. Dougherty (1926) made a similar observation as the result of his experiment in exposing eggs for three successive nights to a temperature of from 28.0 to 32.0° F.

As a general conclusion of the various investigations on the proper temperature at which to hold hatching eggs, it is apparent that about 50.0° F. is the best temperature. In warm weather eggs should be gathered frequently and placed immediately in a temperature of about 50.0° F. In sections of the country where subzero weather prevails in the early hatching season, the eggs should be gathered frequently to avoid the development of abnormal embryos and to secure the best results in hatching.

Having given proper attention to the selection and holding of eggs for hatching, the next problem is to carry out the hatching work so that best results will be secured.

HATCHING WITH HENS

Raising chicks with hens is still practiced to a considerable extent. To be most successful it is necessary to have good brooding hens, properly constructed nests and to give the hens careful attention during the incubation period.

Hens selected for hatching purposes should have the broody instinct well developed, and each should be of such size as to cover properly the required number of eggs. A setting comprises from 11 to 15 eggs, the smaller number being set in the early part of the season, when the weather is cold, and 15 later, when the weather is warmer.

Breeds such as Plymouth Rocks, Rhode Island Reds and Wyandottes are among the best setters. The lighter breeds, such as Leghorns, generally can not be relied upon.

The nest should be made of fine, soft hay, straw or leaves and should be placed in such a position that the hen will not have to fly or jump into it. It should be large enough so that the hen will fill it nicely, affording complete protection for a single layer of eggs, because if it is deep the eggs may pile up and break.

Dust the hens thoroughly with sodium fluoride before setting them. Hens may become so badly infested with lice that they will leave their nests. To dust a hen, take her by the feet, holding her head downward, and rub pinches of sodium fluoride well into her feathers, especially around the vent. The proper method of treating a bird with sodium fluoride is shown on page 432.

Setting hens should be kept in a room that is secluded, slightly darkened, cool and apart from the houses for layers and breeders. A number of hens may be set at the same time but each should be confined to her own nest. They may be fed together, but each hen should return to her own nest and the door of the nest closed.

It is best to set hens after dark because they are less excitable than in the daytime. Each hen may be tested for broodiness by placing 2 or 3 infertile or artificial eggs in the nest the first day. When she is setting well the eggs may be placed under her.

Examine the nests occasionally to be sure that no eggs have been broken, or in case any have been broken the shells and soiled nesting material should be removed and the rest of the eggs washed with warm water to remove any material that came from the broken eggs.

Feed the hens on hard grains, such as wheat, oats, corn, or a mixture of these, and occasionally some green feed. Keep grit and clean water before them always.

At hatching time allow the hens to set quietly after the nineteenth day but be sure that none leaves her nest with the first chicks hatched.

HATCHING WITH INCUBATORS

Selecting an Incubator.—Since the value of the machine is small compared with the value of the eggs used during the normal life of an incubator, it is poor economy to purchase an unreliable machine. The size of incubator to buy depends on circumstances. It takes about as much time to care for a 60-egg machine as for one with a capacity of 360 eggs. Incubators of about 400-egg capacity are well adapted for farm use. Practically all commercial poultry farms, when installing new machines, now purchase the larger or mammoth incubators. Many poultrymen have an incubator capacity large enough to hatch the bulk of their stock in two hatches, thus saving much time in looking after the incubators and brooders and the chickens are more even in size than those hatched when the incubating period extends over several hatches.

The hatching capacity required for the reproduction of the flock from year to year depends on the size of the flock to be reproduced as well as on the number of chickens required to be hatched at one time. In the case of a 200-bird flock, 50 of which are yearlings for breeding purposes and the remaining 150 are pullets, at least 175 pullets should be raised to maturity to allow the culling out of 25 of the poorer pullets. To have 175 pullets in the fall would mean that a flock of 350 chicks would have to be raised to maturity, because practically half the flock would be male birds. If allowance is made for about 15 per cent mortality during the rearing season, 350 chicks in the fall of the year would mean that approximately 420 chicks would have to be hatched. If the chicks are hatched in two successive hatches, 420 chicks would require 210 chicks for each hatch, or about 350 eggs would have to be set each time, which would allow for a 60 per cent hatch giving 210 chicks. For the two hatches, therefore, about 700 eggs would have to be set. (Jull and Lee, 1928.)

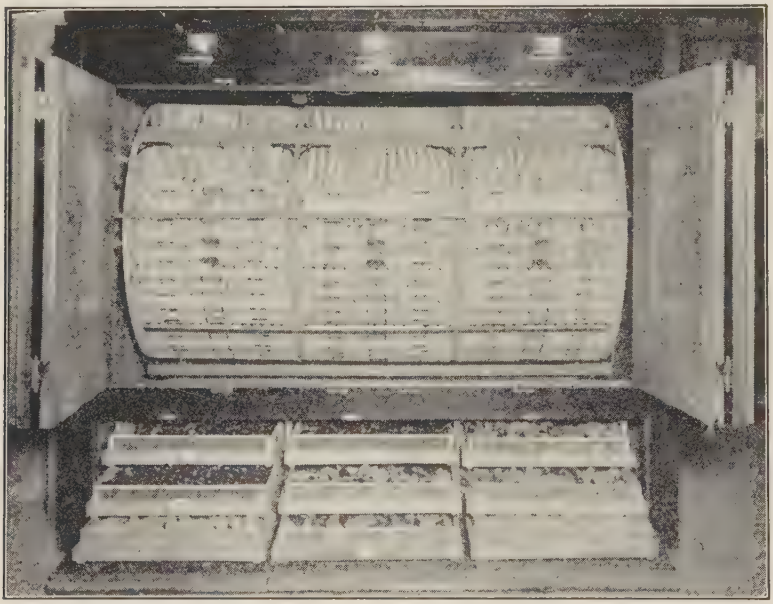

Fig. 66.—A baffle-type incubator heated electrically, the air being stirred by a revolving baffle arrangement. (*Photograph by Petersime Incubator Co.*)

The Incubation Room.—The best kind of an incubator room is one in which the temperature remains fairly constant, where there is good ventilation and where the atmosphere is not too dry. A few small machines may be kept in the cellar or in a room of the house; a well-ventilated cellar usually being much better than a room, because the temperature is subject to less variation and the air usually contains more moisture. When mammoth machines are used, a room especially designed for incubation work should be provided.

A room built especially for incubation should be large enough to allow the attendant to work around the machines conveniently. It should be from 8 to 9 ft. high; it should have a temperature of about 70.0° F., with a relative humidity of not less than about 70, which may be determined by a hygrometer. The shape and size of the room should be governed by the size of the incubators to be installed. Manufacturers of the various mammoth incubators furnish room plans for use with their machines. Many incubator rooms are provided with some system of ventilation in addition to the windows, while in others the ventilation is controlled entirely by the windows. Muslin screens or shutters on the windows provide good ventilation without direct drafts and at the same time keep the sun from shining on the machines. Many incubator rooms have cement floors, which are easier to keep clean than dirt or board floors.

Assembling the Incubator.—Assemble the incubator according to the manufacturer's directions, and see that it is perfectly level by using a spirit level or a shallow pan of water set on top of the incubator. The regulator should work freely. If the incubator door sticks, do not plane it off until the machine has been thoroughly dried.

That there is sometimes considerable variation in different parts of the same incubator chamber has been demonstrated by Harman (1929). Thermometers should be placed in different places in the egg chamber and temperatures compared.

Thermometers.—Test all thermometers once a year with a clinical thermometer, which may be procured from a physician or at a drug store. Place the thermometers, including the clinical thermometer, in warm water, heated to about 103° F., taking care to keep the bulbs near each other and at the same level in the water. Incubator thermometers, if correct, register the same temperature as the clinical thermometer.

Regulating the Temperature.—The printed regulations supplied by manufacturers should be followed closely until experience enables the operator to determine any minor variations that may be desirable. The forced-draft type of mammoth incubator requires a lower temperature than small incubators or mammoth incubators of the section type.

The following suggestions may be useful for those operating section-type incubators: Run the incubator at about 102° F. for at least two days before putting the eggs in. Since it takes several hours for the incubator to come back to its correct temperature after the eggs are put in, the regulator should not be touched during that time. During the 21 days of incubation the temperature of the egg chamber may be regulated by lowering the flame of the lamp or the regulator may be adjusted. The incubator should receive sufficient attention to avoid marked fluctuations in temperature.

The correct temperature to be maintained depends on the position of the thermometer in the egg chamber. The manufacturer's directions should be followed without change unless considerable experience has indicated that they can be improved upon. The possible need of such change is due to the fact that no manufacturer can make a machine and rules to suit all conditions. When the bulb of the thermometer is on a level with the top of the eggs, the temperature should usually be held at 101½ to 102° F. the first week, at 102 to 103° F. the second week, and at 103° F. the third week. At hatching time allow the temperature to go up to 103½ or 104° F. A thermometer suspended about one inch above the eggs should show a temperature of about 102.0 to 103.0° F. the first two weeks and 104.0° F. the last week.

Keep a daily record of the temperature of each incubator. In a good hatch the chicks begin to pip on the evening of the nineteenth day, and most of the chicks will be out of the shell by the morning of the twenty-first day.

Care of the Heater.—In the case of lamp machines always use good oil. Clean and fill the lamp once daily, preferably in the morning, trimming the wick by scraping the charred portion off with a knife or by cutting the wick with scissors. The burners should be kept free from dirt, and after each hatch they should be thoroughly cleaned by boiling. A new wick for each hatch is a good investment, thus eliminating any danger of the wick becoming too short. Turn the eggs before caring for the lamp, so that there will be no chance of getting oil on the eggs. After the lamp is lighted the flame is apt to increase in size, so that it is well to wait a few minutes after lighting the lamp to see that the flame is the proper height.

In the case of incubators heated with coal or gas, the heaters should be thoroughly cleaned at frequent intervals. The flues and pipes should be kept in such condition that the heat supply at all times will be regular.

In the case of electric incubators the heating elements should be inspected and tested before the incubation season begins. The electric wires or coils should never be allowed to get wet and the make-and-break switch should be kept free from oil, dirt and dust.

Position of the Eggs.—A number of experiments have been conducted to determine to what extent hatching results might be affected by the position of the eggs during incubation. In natural incubation the eggs lie on their sides but since the nest is concave the actual position of the eggs tends to be oblique. With this in mind some incubator manufacturers have constructed concave egg trays for their incubators. Other manufacturers, however, make flat trays and in some of these the eggs are supposed to be placed in an oblique position on the trays while in others the eggs must be placed on end and fitted in fairly tight in order that the position of the tray containing the eggs may be altered.

The results of the experiments conducted to determine the influence of the position of the eggs on hatchability suggest that position has some effect. Dareste (1886) found that eggs with the large end up developed normally, while those with the small end up developed abnormally. Graham (1903) and Jackson (1912) found that standing eggs on their small ends for the first three days in order to set more eggs, testing to remove the infertile eggs being done on the fourth day, the hatchability of the fertile eggs was not affected. Eycleshymer (1907) found that the position of eggs did not affect their hatchability, while Bouges (1925) secured slightly better results when eggs were placed in an oblique position as compared with a vertical position.

The general observations of incubator operators is that the position of eggs is not an important matter, particularly in view of the fact that all mammoth incubators are equipped with egg turning devices. In other incubators much time is saved in turning the eggs if they lie in a normal position on the egg tray.

Turning the Eggs.—Turning the eggs during incubation is very necessary to prevent the embryos from becoming stuck to the shell membrane. The setting hen turns her eggs instinctively several times daily, Payne's (1921) observations showing that turning is done as frequently as every hour day and night.

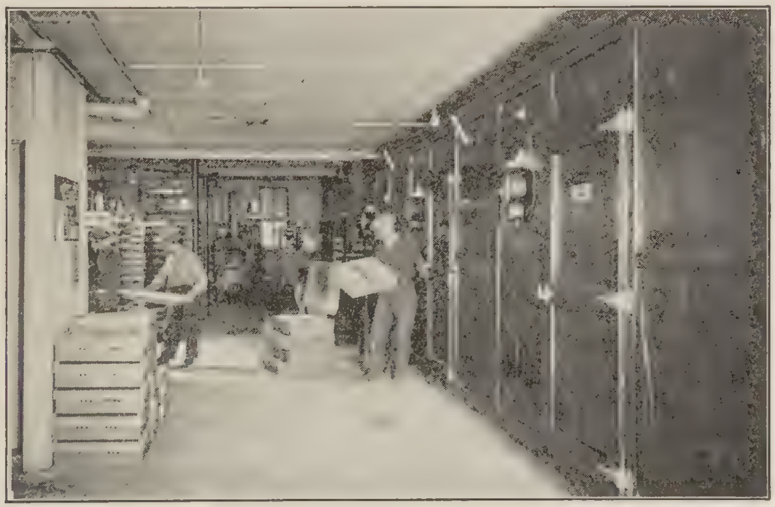

Fig. 67.—Producing chicks by the thousands at a commercial hatchery. Here is shown a series of mammoth incubators of the forced-draft type of air circulation. (*Photograph by Smith Incubator Co.*)

That such frequent turning is not necessary in artificial incubation has been demonstrated as the result of numerous investigations. Dareste (1885) and Jackson (1912) observed that eggs which were not turned did not hatch as well as those which were turned, the former showing that in many cases the embryo became stuck to the shell membrane and development ceased. Dareste (1892) observed that when eggs were rotated at the rate of 90 rotations per minute, the embryos developed normally but never beyond the stage at which the allantois appears. Hannas (1920) secured the best hatches when the eggs were turned twice daily from the first to the nineteenth day. Lamson and Kirkpatrick (1918) secured a hatch of 55.4 per cent of all fertile eggs in eggs that were turned twice daily, and a hatch of 61.1 per cent of all fertile eggs in eggs that were turned five times daily. Payne (1921) found that turning from four to six times daily tends to give better results than less frequent turning. Bouges (1925) observed that turning the eggs during the first two days gave better results than as compared with not turning the eggs during that time. Chattock (1925) found that increasing the number of times the eggs were turned from two to five times daily tended to increase the hatch from 6 to 10 per cent.

Not only is turning the eggs throughout the first 19 days of incubation necessary but apparently the more frequently they are turned the better. It is especially important to turn the eggs the first thing in the morning and the last thing at night in order to make the period of no turning from night to morning as short as possible. In incubators of the cabinet type the problem of turning the eggs is a very simple one and is accomplished by simply shifting the position of the trays containing the eggs by the devices attached to the incubator.

Cooling the Eggs.—The practice of cooling eggs that are being incubated artificially is apparently based on the fact that in natural incubation when the setting hen leaves the nest the eggs are cooled. For many years it was the custom for operators of incubators to cool the eggs daily. Eycleshymer (1907) seemed to think that in artificial incubation cooling is necessary in cases of insufficient ventilation. "It may be stated with a fair degree of certainty that the cooling of the eggs is due to the necessity of obtaining food, and in no way fundamentally affects the growth of the chick when there is an abundant supply of fresh air. There is not the least doubt, however, but what it has a beneficial influence in cases of poor ventilation, and since no incubator is supplied with too much, it probably is best to adopt the common practice of cooling the eggs. In so doing it would not seem advisable to cool the eggs for more than 20 to 30 min. each day for the first 15 or 18 days."

Atwood (1909) secured better hatches and stronger chicks for the most part from eggs that were not cooled as compared with those that were cooled, but observed that "These results indicate that in warm weather, when the circulation of air in the incubator tends to become sluggish, it may be advisable to air the eggs for a reasonable time." Elford (1914) secured better hatches when the eggs were cooled 5 min. daily the first week, 10 min. daily the second week, and 15 min. daily the third week than when the eggs were cooled for shorter or longer periods. Lamson (1918) found no benefit from cooling the eggs either in respect to the number of chicks hatched or the mortality of the chicks. Chattock (1925) observed no advantage in cooling eggs.

In mammoth incubators of the cabinet type, cooling the eggs is apparently unnecessary because of the continuous forced circulation of air. In section-type incubators where there is no forced circulation of air the cooling of eggs is also apparently unnecessary except in cases where the temperature of the incubator has become too high.

Testing the Eggs.—The eggs should be tested twice during the period of incubation, from the fifth to the seventh days to remove all infertile eggs and those with dead embryos, and from the fourteenth to the eighteenth day to remove embryos dying after the first test. White-shelled eggs can be tested on the fourth or fifth day, but embryo development in brown-shelled eggs can not be seen readily by the use of an ordinary egg tester until about the seventh day. Many operators of mammoth incubators make one test about the fourteenth day, removing all infertile eggs and dead embryos at that time.

The testing should be done in a dark room or with a special device that can be used in the daytime. The eggs are tested with the large end up, so that the size of the air cell as well as the condition of the embryo may be observed readily. The infertile egg when held before the testing or candling device looks clear. A fertile egg tested at about the seventh day of incubation shows a small, dark spot, known as the embryo, with a mass of little blood vessels extending in all directions, if the embryo is living. If the embryo is dead, the blood settles away from the embryo toward the edges of the yolk, forming in some cases an irregular circle of blood known as a "blood ring."

At the second test, on the fourteenth day, the eggs containing strong, living embryos are dark and well filled and show a distinct line of demarcation between the air cell and the growing embryo, whereas eggs with dead germs show only partial development and lack of this clear, distinct outline.

Providing Proper Humidity.—It has already been observed on pages 196 to 198 that during incubation eggs lose in weight due to the liberation of carbon dioxide and water. It has also been observed that the developing embryo requires increasing amounts of oxygen as incubation progresses. The respiration that takes place may be put in the form of an equation, as was done by Baumgartner (1881): weight loss + oxygen intake = carbon dioxide output + water given off. The rate of the oxygen intake and carbon dioxide output is determined by the rate of the development of the embryo. The rate at which water is given off is also determined to some extent by the rate of the development of the embryo but probably to a greater extent by the humidity of the air in the egg chamber, the latter being determined very largely by temperature and ventilation.

Dryden (1905, 1907, 1908), from the results of an extensive series of experiments conducted at the Utah and Oregon agricultural experiment stations, concluded that extreme dryness as well as extreme humidity are alike detrimental. His results were consistent in showing that a medium amount of moisture supplied to the egg chamber gave better results than no moisture and a maximum amount of moisture. In the 1907 experiments it was found that the percentage loss in the original weight of the eggs was 17.8 in the case of no moisture, 14.0 in the case of medium moisture and 12.3 in the case of maximum moisture. In the 1908 experiments the comparable percentages were 16.6, 12.8 and 10.8, respectively. In the no-moisture machines Dryden used a sand pan filled with dry sand, while in the medium- and maximum-moisture machines he used sand pans filled with sand kept soaked in water, the pans in the medium-moisture machines being one-half the size of the others.

Day (1908) reports that hatchability was increased to a marked extent by the use of moisture. Atwood (1901) made determinations on the loss in weight in eggs in natural incubation and then determined the approximate amount of water that should be liberated daily per 100 eggs in artificial incubation. His observations are shown in Table 36.

Table 36.—The Normal Loss in Weight in Ounces per 100 Eggs under Conditions of Artificial Incubation
(Atwood, 1901)

Day of incubation	Ounces loss in weight	Day of incubation	Ounces loss in weight
1	1.65	11	18.60
2	3.31	12	20.33
3	4.96	13	22.10
4	6.62	14	23.88
5	8.28	15	25.66
6	10.00	16	27.44
7	11.72	17	29.21
8	13.44	18	30.99
9	15.16	19	32.77
10	16.88		

Lewis (1911*a*), using a sand pan filled with moist sand in incubators operated in a cellar with an atmosphere having a relative humidity of 60 per cent, found that better hatches were secured than when moistened sand was not used. Pearl (1913) also secured better hatches with the use of moisture and suggested, in the case of incubators without sand pans, sprinkling the eggs twice daily with water warmed to a temperature of from 104.0 to 108.0° F.

Lamson and Kirkpatrick (1918), as observed on page 197, secured better results when the relative humidity was between 30 and 70 per cent.

In an electric incubator, to which moisture was added, Burke (1925) observed the following losses in weight in different settings. (See Table 37.)

Walker and Voss (1925) show that in an arid section of the country like New Mexico moisture in the egg chamber is very necessary. Run-

TABLE 37.—PER CENT LOSS IN WEIGHT OF FERTILE EGGS IN AN ELECTRIC INCUBATOR (Burke, 1925)

Weight fresh eggs, grams	Weight, 19th day of incubation, grams	Per cent loss	Weight fresh eggs, grams	Weight, 19th day of incubation, grams	Per cent loss
55.15	43.43	21.24	49.41	39.82	19.41
53.99	43.84	18.79	52.30	42.45	18.81
56.16	45.44	19.09	49.57	40.05	19.18
61.00	48.00	21.30	55.79	46.63	16.42
57.95	45.53	21.42	59.00	46.48	21.23
52.78	41.22	22.00	55.04	45.08	18.20
53.75	43.04	21.90	55.71	44.88	19.40
50.70	41.23	18.67	56.07	45.46	18.90

ning the incubators without moisture gave very poor results, while using a pan of sand kept thoroughly moistened gave considerably better results than using a pan of water or sprinkling the eggs. Elford (1926) secured better hatches by the use of moisture pans than when no moisture was supplied or when moisture was supplied by the use of pads.

Since the relative humidity of the egg chamber is determined very largely by temperature and ventilation, the maintenance of the proper relative humidity in incubators in which the air is mechanically circulated is a relatively simple problem.

In the case of all incubators probably the simplest way to determine whether the proper amount of moisture is being supplied is to weigh the eggs and compare the loss in weight per 100 eggs with the data shown in Table 36 or test the eggs to determine the size of the air cells. Figure 68 shows the relative sizes of the air cell of an egg on the first, seventh, fourteenth and eighteenth days of incubation. The size of the air cell at different stages of incubation indicates approximately the relative humidity of the egg chamber and the amount of ventilation taking place.

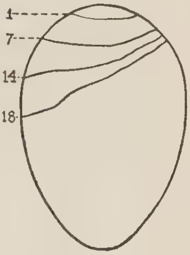

FIG. 68.—Egg showing the normal evaporation of the watery content of the egg on the first, seventh, fourteenth and eighteenth days of incubation. (*Ind. Agr. Exp. Sta.*)

Providing Ventilation.—Ventilation in artificial incubation is necessary in order to provide the developing embryo with oxygen, remove the carbon dioxide given off by the embryos and provide the proper amount of humidity in the atmosphere of the egg chamber. Dryden (1916) points out "that increasing the ventilation without increasing the moisture reduces the number of chicks hatched and gives chicks of lower vitality. This is due to the extreme dryness of the air surrounding the eggs, not to the greater supply of fresh air."

Atwood (1917) observes that more oxygen is required as the embryos develop and the ventilation of the incubator should be increased as incubation progresses. Lamson and Kirkpatrick (1918) determined the effects on hatchability of different rates of ventilation. Ventilation was provided at the following rates of cubic feet per hour: 0.275, 0.534, 0.736, 1.210, 5.390 and 11.290. For the different rates of ventilation the percentage of fertile eggs hatched was as follows: 12.69, 25.75, 42.63, 69.84, 86.00 and 84.74, respectively. The higher rates of ventilation gave the best results. The results are shown in graphic form in Fig. 69.

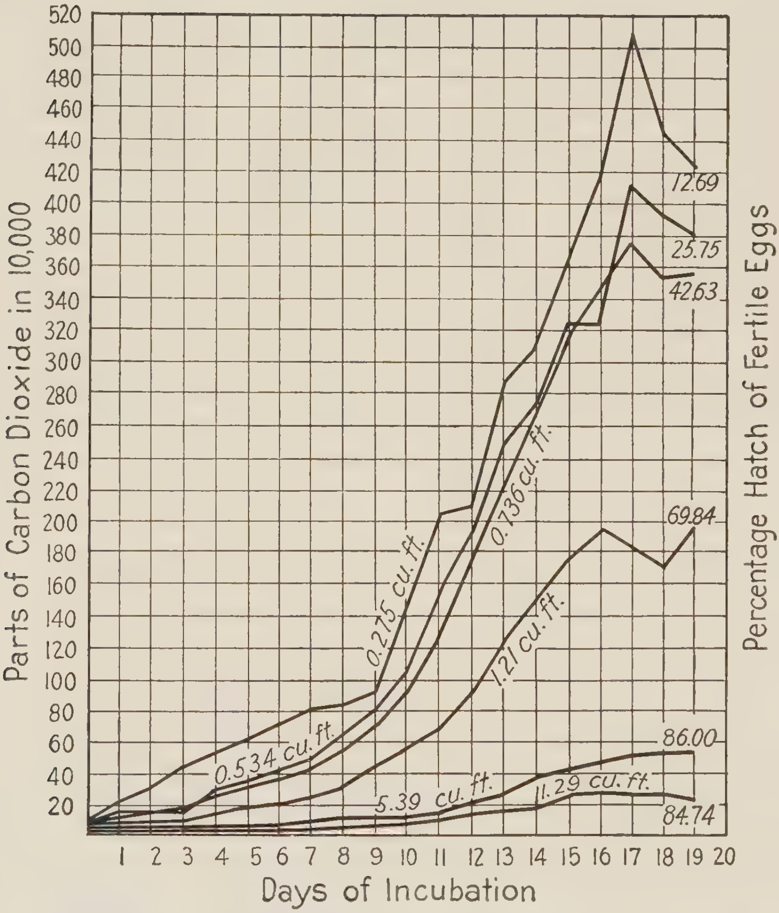

FIG. 69.—The per cent of fertile eggs hatched in relation to carbon dioxide supply, as determined by the amount of ventilation. (*Lamson and Kirkpatrick*, 1918.)

Atwood and Weakley (1924) have determined the approximate amount of fresh air required daily per 100 normally developing embryos to maintain a carbon dioxide content of 50 in 10,000 parts of air in the egg chamber. The data show that the rate of ventilation requires to be increased considerably from day to day, particularly during the last week of the hatch. At the same time, proper precautions should be taken during this time to maintain optimum temperature and humidity conditions.

Taking the Hatch Off.—After the eighteenth day do not open the incubator door until the hatching is well over. Do not open the incubator to see how the eggs are hatching, as this allows the moisture to escape and the temperature to drop. Most incubators are provided with a movable wire piece in the front of the egg tray which is opened when the hatch is completed, so that the chicks as they come to the front of the incubator fall down into the nursery tray where they dry off.

After the chicks are through hatching, remove the shells and eggs with dead embryos and place all the chicks in the nursery trays. Keep the temperature, taken at a level of the chicks' heads, at about 95° F. until the chicks are to be taken to the brooder. When taking the chicks to a brooder put them in a covered box, being careful not to permit them to become chilled while being transferred.

CHAPTER XV

BROODING PRINCIPLES AND PRACTICE

It is essential that the conditions of brooding should be such as to promote the most economical growth and to produce the best quality of market poultry and laying stock. The most important factors in brooding, whether artificial or natural, are sanitation, proper temperature, plenty of room and good ventilation. In natural brooding, however, a uniform temperature and good ventilation for the chicks are supplied by the mother hen, and, owing to the fact that a hen can accommodate only a limited number of chicks, there is little or no danger of overcrowding. At the same time, except where few chicks are being raised, the use of brooders is recommended.

BUYING DAY-OLD CHICKS

Because of the very rapid development of the mammoth hatchery business in the United States, the practice of buying chicks hatched commercially increases from year to year. It is very important that those who buy day-old chicks from commercial hatching establishments pay particular attention to the kind of hatchery from which they purchase their chicks.

The quality of chick produced in a hatchery is determined to a large extent by the quality of eggs used in the hatchery and the methods employed in incubation. Day-old chicks of the highest quality are produced in those hatcheries where the breeders in the breeding flocks producing the eggs for the hatchery are selected carefully, only the best birds being used as breeders. The breeders should always be in the best of health and the poultry plants should be kept in sanitary condition at all times. The eggs sent to the hatcheries should be of good size, as well as uniform in shape, shell color and shell texture. The hatcheries should be kept in strictly sanitary condition at all times, and the management of the incubator should be such as to produce chicks of the highest possible quality. Before placing an order for day-old chicks, buyers should make a careful inquiry concerning flock management and hatchery operation.

SANITATION IN BROODING

Lack of proper sanitation is one of the most frequent causes of failure in brooding chicks. Brooders and brooding equipment used in brooding chicks, brood coops and brooder houses should be disinfected before the brooding season begins and at frequent intervals thereafter. The litter used in brooder houses should be cleaned out frequently, at least once a week during the first three or four weeks, the floors thoroughly disinfected and clean litter supplied. This is very important because the floor soon becomes contaminated and disease is apt to spread from one chick to another.

Contaminated soil is a common cause of poor growth and high mortality in chicks. The chicks should be brooded on land over which the old stock has never been allowed to range, in order to keep the chicks free from intestinal worms and various diseases. A good grass range is most desirable, and chicks should not be brooded on bare land. Do not overcrowd the chicks on the land, and do not use the fields for brooding one year that were used the year previous. The land immediately in front of the brooder house should be treated with lime or acid phosphate, cultivated and sowed to a crop. The importance of keeping the soil in the brooder field sweet and clean can not be over-emphasized.

The importance of sanitation in raising chicks is becoming more thoroughly appreciated by all poultry raisers. Several years ago in Connecticut there was inaugurated a "Grow Healthy Chicks" campaign, the main purpose of which was to demonstrate the value of sanitation in rearing chicks. R. E. Jones (1928) gives an outline of the plan adopted in Connecticut, listing the following eight points which must be adopted:

1. *Clean Chicks.*—Start with pullorum disease-free (bacillary white diarrhea-free) chicks or eggs.
2. *Clean Incubator and Eggs.*—Scrape; scrub; disinfect. Use only clean eggs.
3. *Clean Brooder Houses.*—Scrape clean, scrub with water and lye or disinfectant. (Bichloride of mercury, tablet form, 1 oz. to 8 gal. of water.) Spray with disinfectant; then with whitewash.
4. *Clean Ground.*—Use only ground that has been entirely free from chickens or chicken manure for at least one year.
5. *Clean Litter.*—Use shavings. Clean and renew after first 10 days; then every 5 days thereafter.
6. *Clean Feed in Hoppers.*—Feed only in hoppers that cannot waste or allow feed to become soiled.
7. *Clean Management.*—Avoid traveling from the hens' quarters onto the chick range. Use disinfectants. Keep visitors out!
8. *Clean Laying Houses.*—Scrape clean. Scrub with water and lye or disinfectant. Spray with good disinfectant; then with whitewash.

Table 38 gives the results secured in Connecticut for the years 1926 and 1927, there being 502,938 and 552,882 chicks, respectively, under observation, mortality being based on the number of chickens raised to maturity.

Table 38.—Per Cent Mortality under the Connecticut Grow Healthy Chicks Plan

	Mortality occurring when the following points were adopted			
	All 8 points, per cent	All 8 points except clean chicks, per cent	All 8 points except clean land, per cent	All 8 points except clean chicks and clean land, per cent
1926	7.9	15.3	....	22.0
1927	6.9	14.4	13.9	17.9

The Missouri plan of growing healthy chicks includes the following six points:

1. Hatch before May first.
2. Raise on clean, fresh ground.
3. Feed a growing ration.
4. Brood each hatch separately.
5. Separate cockerels and pullets.
6. Maintain roomy, sanitary quarters.

Under this plan Winton (1928) observed that chick mortality was approximately one-third as high as compared with growing chicks under the methods ordinarily practiced by 31 farmers of Lafayette county, Missouri. The results are shown in Table 39.

Table 39.—Per Cent Mortality under Missouri Plan as Compared with Ordinary Plan of Growing Chicks

Method used	Number farms	Number chicks started	Number chicks raised	Per cent mortality
Missouri plan.....	31	20,784	18,222	12.4
Ordinary methods	31	13,463	8,730	35.4

The first South Dakota plan for growing healthy chicks was adopted in 1927 and contained the following four points:

1. *Clean Ground.*—Chicks were raised on ground not used for poultry during the previous year.
2. *Clean Brooder House.*—Brooder house was thoroughly scrubbed with boiling lye water and then disinfected with a reliable disinfectant.
3. *Clean Chicks.*—Chicks were obtained from parent stock that did not react to a test for the pullorum disease (bacillary white diarrhea).
4. *Clean Feed.*—An all-mash ration was fed in clean hopper or boxes.

In Table 40 are given the results observed by Henderson (1928) when none of the above points or one or more than one was adopted.

TABLE 40.—PER CENT MORTALITY UNDER THE SOUTH DAKOTA PLAN OF GROWING CHICKS

	Total number of chicks hatched	Total number of chicks dead to Aug. 1	Per cent mortality
Followed four-point program	4,403	808	18.3
Followed 3 out of 4 points	8,772	1,742	19.8
Followed 2 out of 4 points	6,477	1,815	28.0
Followed 1 out of 4 points	2,175	625	28.7
Followed none of points	4,590	2,410	52.5

Zumbro (1929) made a survey of the results secured in brooding and rearing 246,782 chicks on 470 farms in Ohio in 1928 and found that on these farms, which followed one or more points in sanitary practice advocated, the mortality up to 10 weeks of age was 18.6 per cent whereas on farms not following any of the points of the sanitation plan the mortality was 34.0 per cent.

In New Jersey the sanitation plan of brooding and rearing chicks contains seven points, which are the same in principle as the Connecticut plan. The mortality results for 1928 and 1929 are shown in Table 41, the data being supplied by Black (1929*b*).

TABLE 41.—PER CENT MORTALITY UNDER THE NEW JERSEY WAGE WAR ON WORMS AND DISEASE PLAN OF GROWING CHICKS

	Number chicks		Per cent mortality	
	1928	1929	1928	1929
Number chicks where all seven points were followed	23,011	68,597	14.2	9.9
Number chicks where all points were followed except for screened manure pit, or wired dropping boards, or daily cleaning of dropping boards	98,922	431,226	17.2	16.8
Number chicks where seven points were followed except for clean brooder, or clean range, or old and young stock separated	177,558	334,879	20.0	19.6

The results secured under the various plans for reducing mortality in brooding and rearing chicks demonstrate the importance of rigid sanitation being practiced at all times. The general conclusions to be drawn from the results secured include the following suggestions:

1. Start with good quality, vigorous chicks that are as free as possible from all diseases, particularly coccidiosis and the pullorum disease (bacillary white diarreha).

2. Maintain an even temperature according to the age of the chicks and the season of the year.
3. Avoid drafts and dampness in the brooder houses and other unfavorable conditions that frequently cause the appearance of disease.
4. Keep the brooder equipment and the brooder houses clean at all times.
5. Remove the litter every week or ten days, at least for the first five or six weeks, and disinfect the house thoroughly at each cleaning.
6. If chicks are allowed on the range, use clean soil, soil on which the older birds have not been allowed to run and which was not used for the chicks the preceding year.
7. Raise the chicks separate from the older birds.
8. Avoid overcrowding, especially in the case of chicks reared in confinement.
9. Provide plenty of hopper space for feed for the chicks.
10. Use wholesome feed at all times.

BROODING CHICKENS WITH HENS

The brooding of chicks with hens is still practiced on many farms and by those raising only a few chicks in the back-yards in towns and cities. Success in raising chicks with hens is dependent largely upon the careful attention given to details of management. It is best that the hen remain on the nest and brood the chickens for about a day after the chicks are hatched. When giving chickens to a hen which already has some to brood it is best to add chicks of the same color and age as those already with her, because some hens often pick the late arrivals if they are of a color different from those already being brooded.

Depending upon her size a hen will brood from 12 to 15 chickens successfully early in the season, and from 15 to 20 in warm weather. Chicks hatched during the cold weather of winter should be brooded in a house or shed; but after the weather becomes more favorable they should be brooded out of doors, using brood coops to confine the hens. Brood coops should be made so that the chicks can run in and out at will but closed at night to keep out cats, rats and other animals, but there should be ventilation enough to give the hen and chicks plenty of fresh air. The construction of brood coops should be such as to permit them to be cleaned easily and disinfected thoroughly. Plans of brood coops may be obtained by writing to the poultry departments of the state agricultural colleges, a list of which is given on page 572.

The hen should be confined in the coop until the chicks are weaned, the chicks being allowed free range after they are a few days old. The coop should be large enough to give the hen plenty of freedom and keep her in good physical condition. It is well to move the coop to fresh ground at least once a week to prevent the soil from becoming contaminated and to give the hen fresh green feed regularly.

ARTIFICIAL BROODING

Artificial brooding is recommended for practically all poultry raisers, especially where considerable numbers of chicks are to be raised. The use of a brooder reduces the amount of labor required in brooding chicks and is more economical when a few hundred or more chicks are raised annually. Also, when the chicks are hatched in incubators or when day-old chicks are bought from a commercial hatchery, the brooding of chicks with brooders is a practical necessity.

Brooders may be classified as follows: lamp brooders holding from 25 to 100 chicks; electric brooders of various sizes, accommodating from 50 to 500 chicks; stove brooders heated by coal, kerosene or distillate oil, with a capacity varying from 200 to 1,000 chicks; hot-water-pipe systems, the capacity of which is unlimited; and battery brooders especially designed for brooding chicks in confinement.

Lamp Brooders.—Lamp brooders usually use kerosene oil as the source of heat. The danger from fire caused by carelessness or lack of proper attention makes it practically necessary to use lamp brooders in small brooder houses located at some distance from larger buildings. In attending the lamp care should be taken to keep the wick and burner properly cleaned. Brooder lamps should be inspected several times a day. Do not fill the lamp entirely full of oil, because the heat from the lamp will expand the oil in the bowl and may cause it to overflow and catch fire.

Electric Brooders.—Electric brooders are being used more extensively each succeeding year, especially in those sections where the cost of electric current is comparatively low. The current must be dependable at all times during the brooding season, because if it is off for a few hours the chicks may become chilled, causing high mortality. In many sections of the country, especially where chicks are brooded early in the season, it is necessary to heat the brooder room with an auxiliary

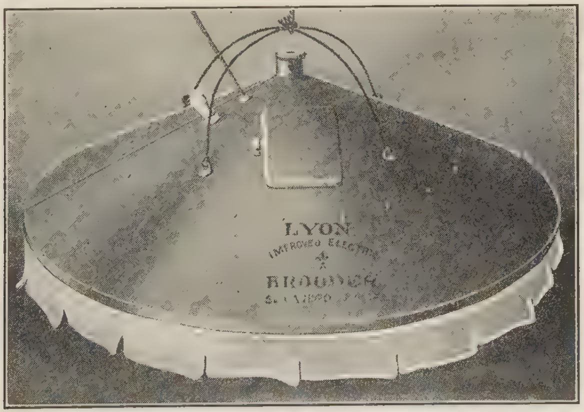

Fig. 70.—An electric brooder of the convection type. Heavily insulated hover with double-zone brooding space. (*Photograph by Lyon Electric Co.*)

heating system to a temperature of from 60 to 70° F. in order to maintain the proper temperature under the hover of an electric brooder.

Dougherty (1927) discusses the use of electric brooders and makes the following observations:

> Electricity as a source of heat for brooding chicks has proved very popular with poultry keepers in California because of its convenience. Only two objections seem to stand in the way of it being used much more extensively for brooding and incubation than it is at present. These are dependability of supply and high cost per kilowatt-hour. When the power companies reduce the liability of interruption to the supply of current from a major to a minor hazard and reduce the net cost to compare favorably with other sources of heat, electric heating will probably displace other methods for brooders and incubators wherever it is obtainable by poultry keepers.

Electric Brooder Requirements.—Moses and Wood (1927) made quite an exhaustive study of methods and costs of brooding chicks with various types of electric brooders. Among the requirements in electric brooders they enumerate the following:

> (1) The heating elements should be so arranged as to obtain a uniform distribution of heat and, if possible, to assist in ventilation. (2) A thermostat for temperature regulation should be provided. (3) Adequate ventilation is essential to introduce fresh air and to remove the excess carbon dioxide, water vapor, and other impurities as they are formed. (4) The brooder should be simple and well built. It should be so designed and constructed as to simplify operation, minimize costs and insure satisfactory brooding conditions. (5) The first cost as well as operating costs must be such as to render the use of the brooder profitable.

They point out that the electric brooder is heated with electric heating elements and makes use of radiation, convection, or conduction for transferring heat from the elements to the space occupied by the chicks. They enumerate the following safety precautions in working with any electrical circuit:

> (1) Never attempt to work with a "hot" or live circuit. Open the circuit switch or remove the circuit fuses first. While 110 volts will seldom injure one, there are conditions under which it may be injurious. (2) Consider all electric wires "hot" unless you have opened the circuit yourself or know it to be open. (3) If a shock is received from the ordinary electrical appliances, determine the cause at once. It generally indicates poor electrical insulation. (4) Never work with a power circuit when standing on wet ground or wet floors, or when in water. (5) Never allow the body to become a part of a circuit. The body can form a circuit either to "ground" or to the opposite power "leg." (6) Always remember that both legs of an alternating-current circuit as usually operated are "live." (7) Fuse the circuits on both legs and fuse for about 125 per cent of full load. These fuses will protect your electrical apparatus and the circuit.

Operating Electric Brooders.—The brooding of chicks with electric brooders is discussed by Dougherty (1929), who offers the following advice regarding the best type of electric brooder: "Simplicity, durability, accuracy of regulation, effectiveness of ventilation, effectiveness of insulation, convenience for operation, cleaning and repairing these are the characteristics of a good electric brooder. A brooder is a tool for a very definite purpose and its value depends on its ability to serve that purpose to the fullest extent."

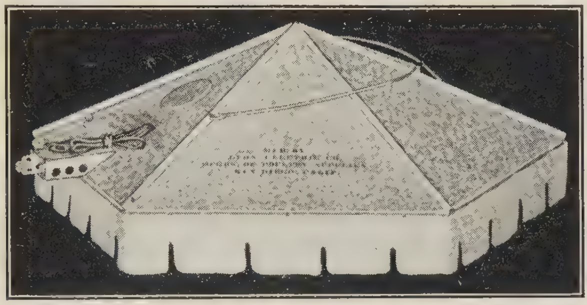

Fig. 71.—A type of electric brooder with a sectional knockdown canopy with portable heating arrangement. This brooder has a reverse air movement from those of the average convection type. (*Photograph by Lyon Electric Co.*)

Garver and Carver (1929) make the following observations regarding the successful operation of electric brooders:

> It is important for the successful operation of electric brooders to have a reliable source of electric current that is not subject to frequent or long interruptions.
>
> The brooder room or house should be of double walled construction with a ceiling not more than seven feet from the floor. A well-constructed brooder house is necessary to conserve the heat generated by the brooder and to make the cost economical.
>
> Electric brooders equipped with curtains are much more economical to operate under the climatic conditions encountered in the state of Washington.
>
> The ventilation of the electric brooder is very important and can best be solved by placing the brooder on a half-inch mesh hardware cloth frame raised two to four inches from the floor. This permits of constant circulation of air and keeps the floor of the brooder clean, dry, and sanitary.
>
> Chicks brooded under electric brooders, on wire floors for an eight-week period, are not affected with coccidiosis.
>
> The electric brooders maintain an absolutely even and regulated temperature because of control by the automatic thermostat. The low mortality records demonstrate the excellent results of uniformity in temperatures through the first few weeks of brooding.
>
> The electric brooder because of its simplicity of operation and low per cent of mortality is especially recommended for the poultryman who is inexperienced in brooding chicks.

The electric brooder requires practically no time to operate as there are no lamps to fill nor fires to tend.

The hover attraction light used inside the curtain on nearly all electric brooders solves the poultryman's problem of hovering his chicks each night. The hover attraction light does this for him.

The electric brooder is more adaptable for the roosting of chicks as the forced roosts can be placed under the hover and the hover slightly raised by a pulley and bag of sand, permitting the chicks to roost in the same location. As the chicks become older the hover is raised a little every few days until the chicks are left entirely without heat on the forced roosts. This roost is placed under the brooder when the chicks are four to five weeks old.

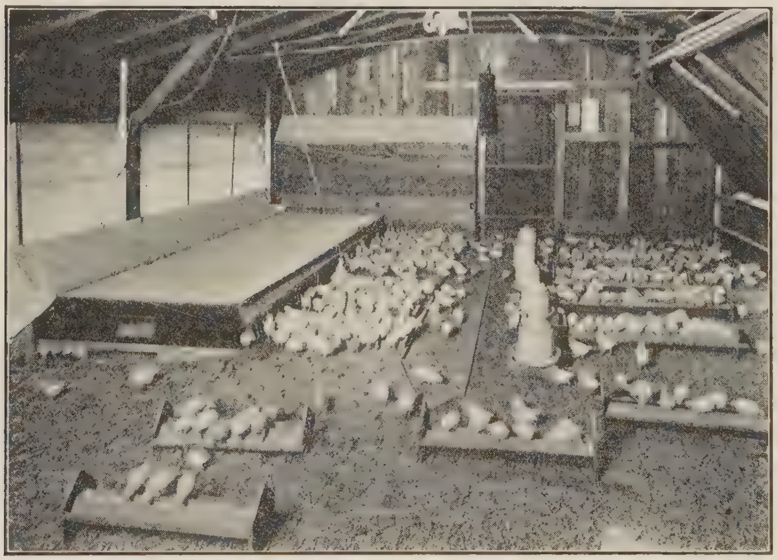

FIG. 72.—Brooding chicks with the "underheat" electric brooder. The heating units are placed under the floor of the brooder house. (*Photograph by St. Helens Incubator Co.*)

Especially when the brooder is set on a wire frame there is practically no fire risk such as may be encountered with other types of brooders.

Stove Brooders.—Brooders heated by coal are coming into very general use everywhere, especially where hard coal is readily available, while similar brooders heated with engine distillate oil are used extensively on the Pacific Coast. These brooder stoves have a capacity of from about 250 to 1,000 chicks each, but the brooding of not more than 350 chicks in one flock usually gives better results than when larger numbers are brooded together. Jull and Lee (1928*a*) describe stove brooders in the following terms:

> Most of these stoves have hovers, although a few of the oil stoves do not. A stove with a hover is preferable. The use of hard coal of chestnut size is

advised for the coal-burning brooder stoves, although in some sections where hard coal can not be obtained and soft coal is abundant the latter may be used, but in that case the brooder requires more frequent attention. Most of the oil brooders are equipped with a wafer regulator that controls the flow of oil, which is fed automatically from a tank or barrel outside the house. Several stoves may be connected with the same supply tank. This brooding system provides good ventilation and heat enough to keep the chickens from crowding and requires a minimum of care. Brooder stoves heated by kerosene are used somewhat in the East, but their use is not nearly so common as that of the coal-heated brooders, and they have not proved to be so satisfactory. In the colder parts of the country it is frequently difficult to get heat enough from kerosene-heated stoves when brooding chicks early in the season.

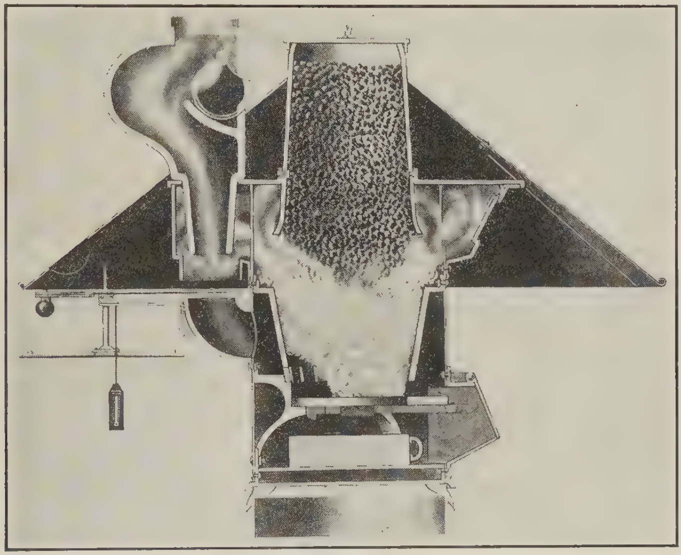

FIG. 73.—The coal-burning brooder stove is one of the most successful ways of brooding chicks in colony-brooding houses, where the chicks are given range. (*Photograph by Buckeye Incubator Co.*)

Hot-water-pipe Brooders.—The system of hot-water-pipe brooders consists of long brooder houses heated with hot water, coal or gas being used for fuel.

Many of the latest of these mammoth brooders are giving good results, and the labor of brooding a large number of chickens is less than when small brooders are operated. These brooders are suitable for very large farms or where broilers are raised during the winter months. Plans and specifications for brooder houses for hot-water-pipe brooders may be obtained from the manufacturers. If winter chickens are being raised it is advisable to heat the brooder house by placing brooder pipes around the outside walls of the brooder house, keeping the room temperature at from 60 to 70° F., regardless of the temperature of the hover. The need for this room heat depends largely on the brooding system and on weather conditions, but it is usually necessary in order to maintain the desired temperature under the hover (Jull and Lee 1928*a*).

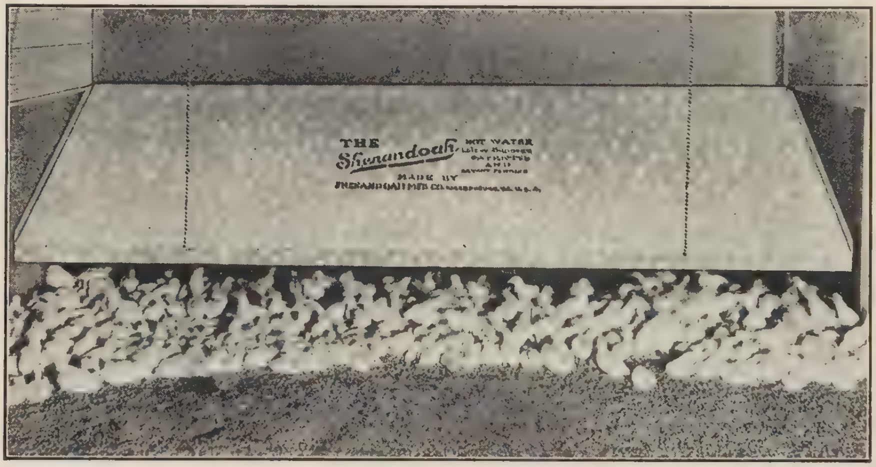

FIG. 74.—One section of a continuous hot-water-pipe brooding system. (*Photograph by Shenandoah Mfg. Co.*)

FIG. 75.—The hot-water-pipe brooding system is used by many poultrymen, both for the production of boilers and for the raising of pullets for egg production. (*Photograph by Shenandoah Mfg. Co.*)

Battery Brooders.—Battery brooders are built on the same principle as battery-fattening crates and consist of single or double tiers of compartments one above the other, as illustrated in Fig. 76. Battery brooders are especially adapted for brooding chicks in confinement and have a particular use in connection with commercial hatcheries for brooding chicks for two or three weeks. There are two kinds of battery brooders on the market, those equipped with an electric brooder in each compartment and those that depend entirely upon the temperature of the room in which the brooders are kept for supplying the necessary heat to the chicks.

The use of the battery brooder reduces the amount of labor required to brood a given number of chicks. Also, worm infestation and various diseases to which chicks are susceptible are more readily controlled than in brooders where the chicks have access to the ground, since in the battery brooders the chicks are kept on wire mesh through which the droppings pass to galvanized pans for each compartment. At the same time, care must be exercised to prevent toe picking, feather picking and cannibalism when chicks are brooded in battery brooders. Many operators of battery brooders tend to use excessively high temperatures and keep the brooder rooms too dry.

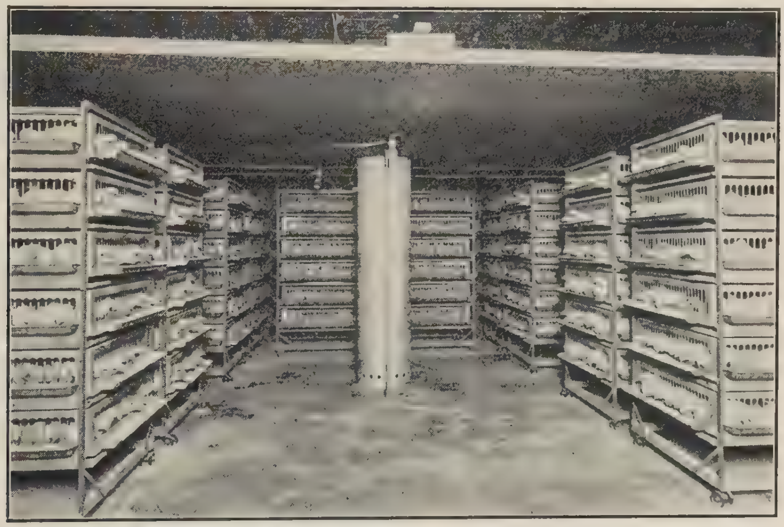

Fig. 76.—The use of battery brooders is a very satisfactory way of brooding chicks for the first few weeks. (*Photograph by Kerr Chickeries.*)

A mammoth battery brooder, built on much the same principle as the cabinet-type incubator, is used in connection with some commercial hatcheries for the purpose of holding chicks for a week or two.

Home-made Brooders.—In some sections of the country where hard coal is difficult to obtain and the rates for electric current are high, home-made brooders have been devised that burn wood or soft coal. Trollope and Gowder (1929) describe a home-made brick brooder that burns green hardwood and gives satisfaction.

Selecting a Brooder.—The selection of the brooder is a very important matter because the successful brooding of chicks is frequently a difficult problem. Cheap, unreliable brooders may easily ruin many broods of good chicks. A reliable make will more than repay the difference in cost between it and a poor one in the first brooding season through lessened mortality and better growth of the chicks. Above all, be sure that the brooder is made of good material and that the thermostat is well made. The latter is a particularly important feature, because a poorly made thermostat or one that gets out of order readily may allow the temperature to rise until the brood of chicks is ruined or the temperature may drop so low that the chicks get chilled and contract pneumonia or some other disease.

For those who raise about 400 chicks annually, two brooder stoves would be satisfactory, one for the first hatch and another for the second. For those who raise about 800 chicks annually four brooder stoves would be sufficient. They are not expensive to operate and save much time in caring for the chicks.

Operation of the Brooder.—The following remarks with several modifications are taken from Jull and Lee (1928*a*): Chickens are usually left in the incubator from 24 to 36 hr. after hatching, without feeding, before they are removed to the brooder, which should have been in operation three or four days at the proper temperature for receiving chickens. A beginner should try his brooding system carefully before he uses it. Early mortality in chicks is frequently a result of the chilling

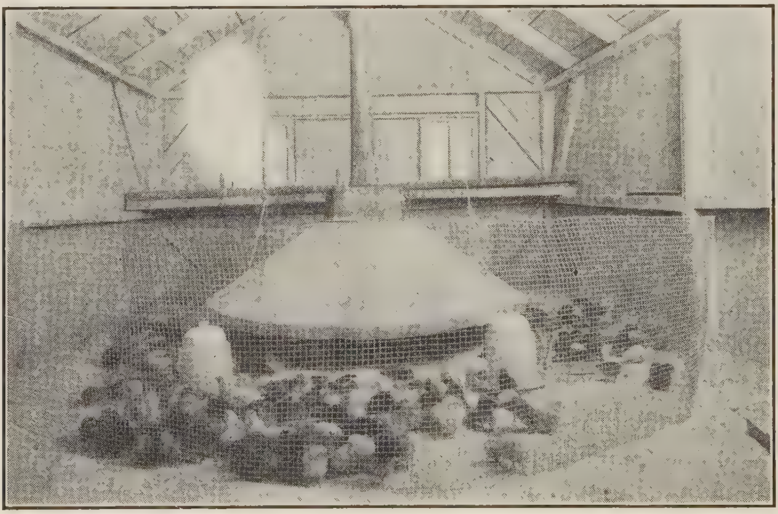

FIG. 77.—A wire netting surrounding the brooder stove at some distance from it helps to keep the chicks near the source of heat. This is an important matter for the first few days of brooding. (*Photograph by U. S. Dept. Agr.*)

they receive while they are being taken from the incubator to the brooder and also the result of not having the brooder running properly when the chicks are first put under the hover. In cool or cold weather the chicks should be moved in a covered basket or other receptacle.

The floor of the brooder house should be covered with about one inch of cut clover, alfalfa, straw or shavings. In case neither cut clover nor alfalfa can be obtained, sand may be used, although if the chicks are not fed properly they are inclined to eat the sand, and that sometimes causes loss. The litter should be removed frequently, as cleanliness is essential in raising chicks.

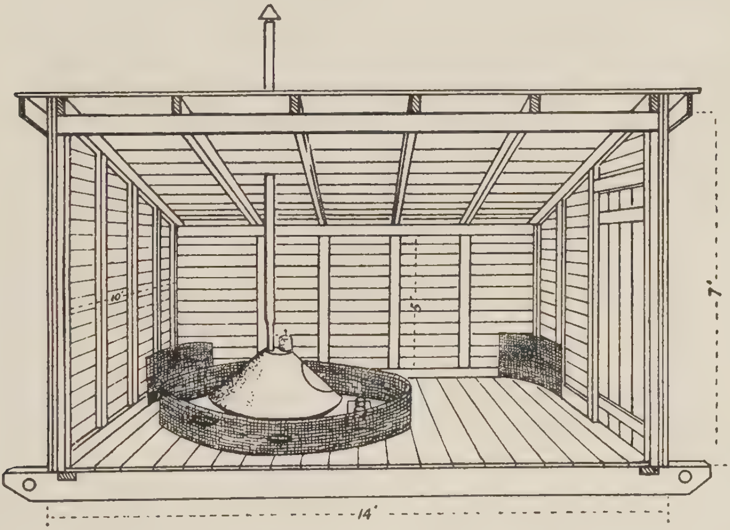

FIG. 78.—Showing the inside view of brooder house, brooder stove at one end with temporary enclosure for chicks, which is removed after the third or fourth day. All corners should be wired off as illustrated. Double-board floor with paper between is recommended instead of single as shown in plan. (*Alta. Dept. Agr.*)

At first when chicks are put into the brooder they should be confined under or around the hover by placing a board or wire frame or guard a few inches outside, as shown in Fig. 77. The fence or guard should be moved farther and farther from the hover and discarded entirely when the chicks are three or four days old or when they have learned to return to the source of heat. The chicks should be watched closely to see that they do not huddle or get chilled. If they begin the bad habit of toe picking, remove the wounded ones and paint their toes with tar. Getting the chicks outdoors will serve to check the habit.

Regulating the Temperature.—The best temperature at which to keep a brooder depends on the position of the thermometer, the type of the hover, the age of the chicks and the weather conditions. Aim to keep the chicks comfortable. When too cold they will crowd together and try to get nearer the heat. If it is found in the morning that the droppings are well scattered under the hover it is an indication that the chicks have had heat enough. If the chicks are comfortable at night they spread out under the hover of the brooder, and the heads of some protrude from under the hover. Too much heat causes them to pant and gasp and sit with their mouths open. Excessive heat tends to weaken the vitality of the chicks.

It is impracticable to state the temperature at which brooders of each type should be kept. In most cases the brooder should be run at about 100° F., when the chicks are first put in, and the stove brooders should be kept at that temperature for the first few days, because the chicks are able to adjust themselves to the heat, moving nearer or farther from the heat, according to the outside temperature. The temperature is lowered, of course, as the spring season advances and as the chicks begin to feather out.

Lewis (1911*b*) recommends a temperature of 100° F. for the first week, 96° F. for the second, 92° F. for the third, 88° F. for the fourth, and then reduced gradually until no more heat is required. Smyth (1923) recommends a temperature of 95 to 100° F. at the start, decreasing it gradually. Thompson and Clickner (1927) suggest a temperature of 100° F. at the start, dropping it to 95° F. toward the end of the first week. Moses and Wood (1927), in the case of electric brooders, suggest a temperature of 90 to 95° F. two inches above the floor and five inches inside the outer edge of the hover under all weather conditions.

In brooders in which chicks do not have equal opportunity to adjust themselves to the heat the temperature is gradually reduced to 85° F. for the second 10 days, and then lowered to 70° or 75° F. and kept there as long as the chickens need heat. This depends somewhat on the season of the year and the number of the chickens, as it can be readily seen that the heat generated by 350 chickens would raise the temperature under the hover to a higher degree than the heat given off by a smaller number; consequently, the heat furnished by the lamp or stove must be regulated accordingly. As the chickens grow larger and need less heat, the heat may be supplied only at night and later only on cold nights. Care should be taken to prevent chilling the chickens, which weakens them and may result in bowel trouble. Also, overheating is to be avoided since Dougherty (1923) has observed that "too high temperatures tend to reduce the vitality of the growing stock and develop 'hot-house' chicks." The heat is usually cut off after the chickens are well feathered.

Providing Ventilation.—The proper ventilation of the brooder is necessary, since water vapor and carbon dioxide given off by the chicks tend to accumulate beneath the hover of the brooder when curtains are used or when the ventilation is restricted. Dougherty (1923) emphasizes the importance of adequate ventilation both under the hover and in the brooder house. He offers the following suggestions:

Unless a hover has a positive system of fresh air ventilation, it should not sit so close to the floor as to restrict a free circulation of air beneath. Curtains, if used, should hang at least one or two inches above the floor at first and be gradually raised higher as the chicks become older and stronger. With oil and gas brooder stoves which discharge the products of combustion directly into the air of the hover, the lower edge of the galvanized iron canopy should be not less than four inches above the floor and curtains should not be used.

FIG. 79.—Teaching the chicks to roost early is not only the best way of insuring their comfort but also reduces mortality. (*Photograph by U. S. Dept. Agr.*)

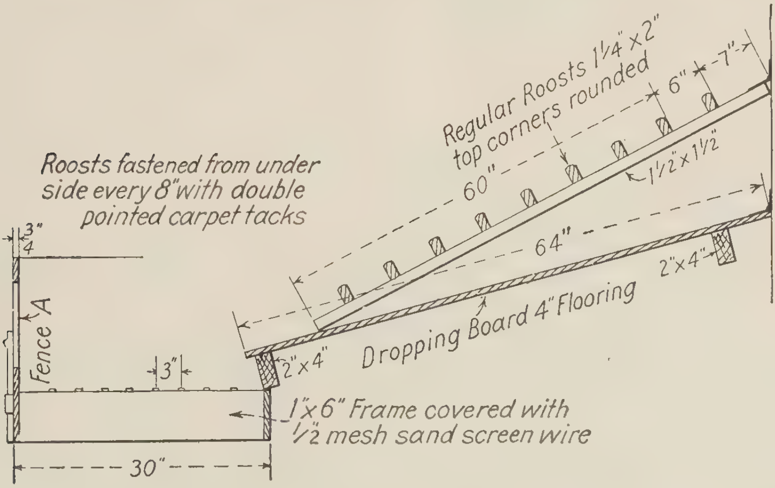
Regular Roosts 1¼" x 2"
top corners rounded
6"
7"
1½" x 1½"
60"
64"
2" x 4"
Dropping Board 4" Flooring
2" x 4"
Roosts fastened from under side every 8" with double pointed carpet tacks
3/4"
Fence A
3"
1" x 6" Frame covered with ½" mesh sand screen wire
30"

FIG. 80.—A device for teaching chicks to roost while quite young. (*After Shoup*, 1927.)

Moses and Wood (1927) make the following pertinent observation:

> Ventilation for the purpose of removing impure air and introducing fresh air affects both the amount of heat used and the quality of chick produced; but *the health of the chick should never be jeopardized in order to save a little heat.* The slight cost of the additional heat necessary to secure adequate ventilation is more than offset by the lower mortality of chicks and by the stronger chicks which are produced when all conditions are fully met.

When the chickens are fairly well feathered, low roosts should be placed in the rear of the brooder house. A device of Shoup's (1927) for teaching chicks to roost early is illustrated in Fig. 80. The chicks will soon learn to roost, and this will prevent overcrowding on the floor. It is advisable to place wire netting under the roosts, as shown in Fig. 81. Poultry raisers should bear in mind that chicks grow rapidly and frequently do not get ventilation enough if allowed to sit on the floor when a few weeks old.

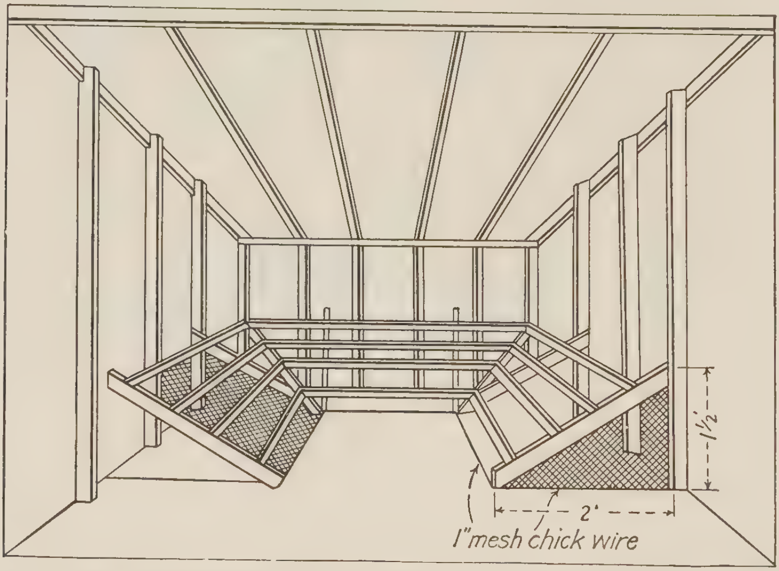

Fig. 81.—Chick roosts arranged in the brooder house to encourage early roosting. Wire netting prevents the chicks from crowding into the corners and keeps the chicks away from the droppings. (*Ill. Agr. Exp. Sta.*)

Providing Plenty of Room.—It is a common practice on the part of many to brood too many chicks together. When it is realized that chicks usually double their original weight in less than two weeks, Jull and Titus (1928) and Titus and Jull (1928), it is readily understood how quickly they may become overcrowded if too many are placed under the brooder at the start. The larger the number of chicks brooded together usually the slower the growth and the greater the mortality.

On the other hand, since the larger the number that can be brooded together the less the amount of labor per chick required in caring for them, it becomes a question of the most economical number to brood together. Better growth and less mortality will more than compensate for a little extra labor required in brooding chicks in limited numbers per flock.

Card and Kirkpatrick (1918) advise 25 sq. ft. of floor space for each 100 chicks and recommend brooding together not more than 500 chicks. Dougherty (1927) recommends 7 sq. in. of hover space per chick and says that a hover 42 in. in diameter has a capacity of 200 chicks and a hover 52 in. in diameter a capacity of 300 chicks. He further says that ½ sq. ft. per chick is not too much floor space for chicks less than 5 weeks of age. According to this 100 chicks would require a room containing 50 sq. ft. Moses and Wood (1927) suggest that when using electric brooders, at least 7 sq. in. of floor space per chick should be provided.

Buster and Newlon (1924) made a survey of brooding practices in California and found that mortality was greatly increased as the floor space per 100 chicks was reduced. Their data are shown in Table 42.

TABLE 42.—PER CENT CHICK MORTALITY IN RELATION TO FLOOR SPACE PER 100 CHICKS

(Buster and Newlon, 1924)

Floor space per 100 chicks	Number of chicks	Mortality	Per cent mortality
Less than 35 sq. ft.	73,007	19,254	26.3
35.0 to 49.9 sq. ft.	25,371	4,122	16.2
50.0 sq. ft. and over	25,044	3,484	13.1

The data in Table 42 indicate that 50 sq. ft. floor space per 100 chicks is desirable in order to reduce mortality to the minimum.

Brooding Chicks in Confinement.—In some sections of the country, especially where commercial poultry raising is carried on extensively, chicks are brooded in confinement for the first few weeks. A number of years ago this practice was followed where broilers were being produced commercially but was abandoned as a general practice because of trouble experienced in leg weakness in the chicks and because of the heavy mortality frequently encountered.

More recently, however, the practice has been resumed as a result, largely, of the discovery that proper proportions of vitamin D in the ration prevent leg weakness. Another reason for the resumption of the practice was that when chicks were reared on the same ground year after year various troubles were frequently encountered, such as coccidiosis, intestinal roundworms and tapeworms. Poultrymen found that soil which had been allowed to become contaminated with disease germs and infested with worm eggs was an unsafe place on which to attempt to raise chickens. Brooding chicks in confinement was adopted as an alternative to providing new range or cleaning up the old range.

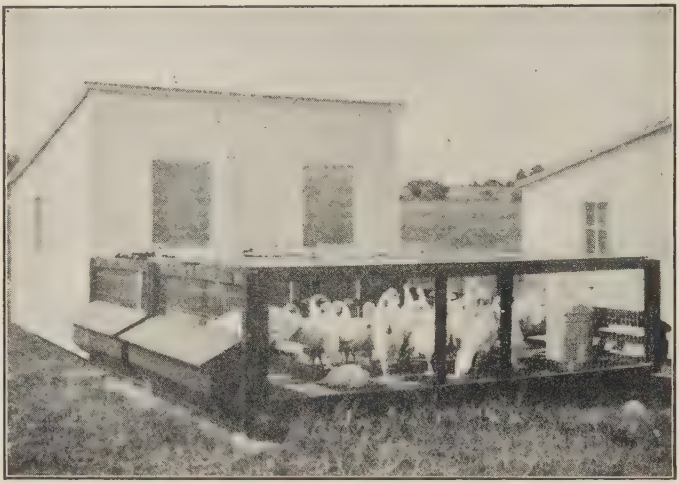

FIG. 82.—Confinement rearing with a sun porch, using ¾-in. wire mesh, for the bottom, with 1-in. mesh siding. The feed hoppers are placed on the outside of the sun porch. (*Photograph by Wm. C. Monahan.*)

One outstanding advantage in brooding chicks in confinement is the saving of labor, particularly in the case of large numbers of chicks. A hot-water-pipe brooder is frequently used in a long brooder house, which is divided into a number of pens, each large enough to accommodate from about 350 to about 1,000 chicks. Such an arrangement requires much less labor in tending the chicks than is the case when the chicks are brooded under the colony brooding system, with the colony houses 100 ft. or more apart. This saving of labor is an important matter and so, also, are mortality and the rate of growth of the chicks.

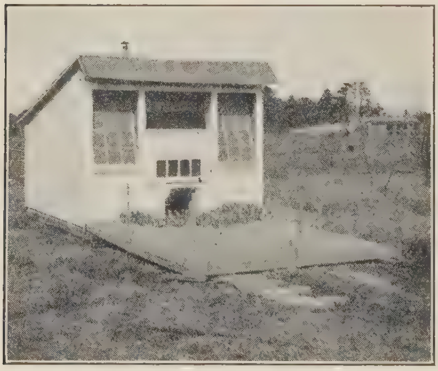

FIG. 83.—A colony brooder house equipped with a sun porch, the latter consisting of a concrete slab in front of the house. The chicks are kept off of the ground but are given access to sunlight. (*Photograph by Wm. C. Monahan.*)

The battery brooder system is being used extensively in the brooding of chicks in confinement. In this system the amount of labor required to brood the chicks is reduced. Also most of the diseases normally affecting chicks are easily controlled, although considerable care must sometimes be taken to prevent toe picking and cannibalism from developing.

Dangers in Confinement Brooding.—Brooding chicks in confinement serves as a precaution against intestinal-roundworm infestation and also serves to avoid losses from coccidiosis, provided the organisms of that disease are not taken into the house in litter or on the feet or with the feed. Should that happen, and coccidiosis gains an entrance into a long brooder house containing several thousand chicks, the losses may be heavy. Also, brooding chicks in confinement is not necessarily a safeguard against tapeworm infestation, but undoubtedly the amount of infestation is reduced materially. The danger from diseases and parasitic infestation is lessened considerably if the brooder house floors are constructed of hardware cloth, which is made of ½ in. mesh wire nailed to 2 by 4 in. pieces of wood. The droppings pass through the wire mesh and the pens are kept quite clean.

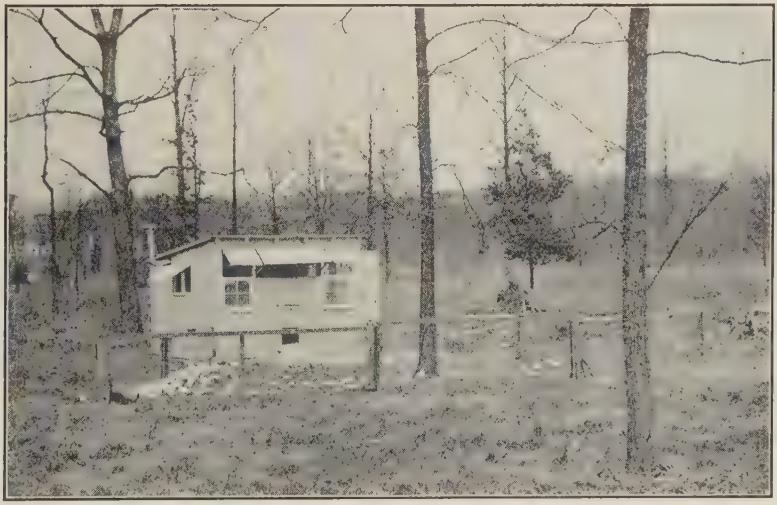

FIG. 84.—The chicks are given range but for the first few days are confined to a limited range in front of the brooder house. (*Photograph by U. S. Dept. Agr.*)

Several other troubles are frequently encountered when chicks are brooded in confinement. Toe picking, tail picking and body picking are three bad habits that sometimes develop. Toe picking is usually the first trouble to make its appearance and may develop when the chicks are but a few days old. Tail picking may develop shortly after feathers have replaced the down, and body picking sometimes occurs as an aftermath of tail picking. Many poultrymen who have experienced considerable losses from these three troubles are at a loss, for the most part, to ascribe any particular cause or to suggest a definite remedy. Any one of the three troubles may occur when good rations are being fed and when all conditions of brooder management are considered satisfactory. Experience has taught that one of the best ways of avoiding all trouble is not to overcrowd the brooders.

Darkening the windows and painting the inside of the brooder house blue seems to be of some assistance in avoiding the troubles, particularly in the case of toe picking. Where tail picking and body picking develop, however, probably the wisest thing to do is to allow the chicks outdoors.

One thing is certain, when chicks are brooded in confinement the brooder house must be kept in a strictly sanitary condition at all times. The litter should be removed weekly and the house disinfected frequently.

Advantages of Confinement Brooding.—Various aspects of brooding chicks indoors are discussed by Kennard (1924), Bethke and Kennard (1924–1925), and Charles and Knandel (1928), who recommend brooding in confinement in the following terms:

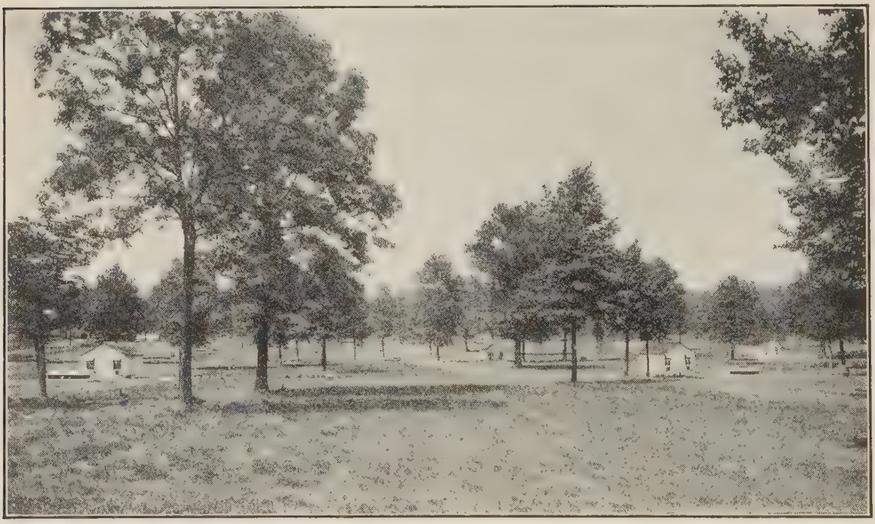

Fig. 85.—Good range and plenty of shade are important factors in the successful rearing of pullets to maturity. This scene shows the method of rearing chicks at the U. S. Animal Husbandry Experiment Farm at Beltsville, Md. (*Photograph by U. S. Dept. Agr.*)

> Brooding in confinement has many advantages: (1) It gives an opportunity for careful supervision. (2) It allows a constant, accurate check on all chicks. (3) It is possible by this method of brooding and rearing to obtain definite, accurate data on feed consumption and feed costs. (4) It prevents loss from hawks, crows, and vermin. (5) It avoids the intermingling of various ages as on free range. (6) It makes it necessary to remove the cockerels at 6 or 8 weeks of age. This is an advantage because it allows more room for the pullets to mature. (7) Labor costs are not increased. In fact, chicks are handled more easily by this system than when allowed free range. (8) It tends to prevent thieving.

(9) It allows rigid sanitation. (10) Chicks raised in confinement mature 3 to 4 weeks in advance of those allowed free range. (11) Chicks brooded by the system of confinement described are free from intestinal parasites.

Although brooding chicks in confinement saves labor, it also requires more careful management to avoid losses than when chicks are reared on range under the colony system, especially if new land is used each year. Not only do chicks brooded in confinement need more careful attention than chicks brooded on range but also there is greater danger of overcrowding the houses, especially if the chicks are kept beyond the broiler stage. Charles (1927) describes the possibilities in producing broilers out of season and observes that the costs of producing broilers are divided as follows: feed, 46.79 per cent; labor, 22.42 per cent; chicks, 21.73 per cent; coal, 9.06 per cent; although these costs do not include depreciation on equipment and interest on investment.

For the production of broilers on a commercial scale, brooding in confinement has been proved to be satisfactory, but where pullets are being raised for laying purposes it is undoubtedly advisable to give them range on clean soil, at least after the first three or four weeks.

CHAPTER XVI

REARING PRACTICE

The proper management of the growing stock during the summer months is of vital importance if best results are to be secured. The brooding period is over and brooders are no longer necessary, but other problems arise which require careful attention. The all-important problem of rearing chickens under sanitary conditions, discussed in the previous chapter, should not be overlooked.

REARING ON RANGE

The amount of range to be provided for the growing stock is a very important matter. Too often insufficient range is provided, with the result that the land soon becomes bare and polluted with droppings containing worm eggs and disease organisms. For each 100 chicks there should be range available amounting to approximately 100 by 100 ft. and this range should be kept with a fresh green crop. After the chickens have been removed from the houses, the land in the immediate vicinity should be limed heavily, ploughed and sown to a green crop to be ready for chicks again in two years if this range is required in that time. It is advisable to rear young stock on land that has not been used the previous year.

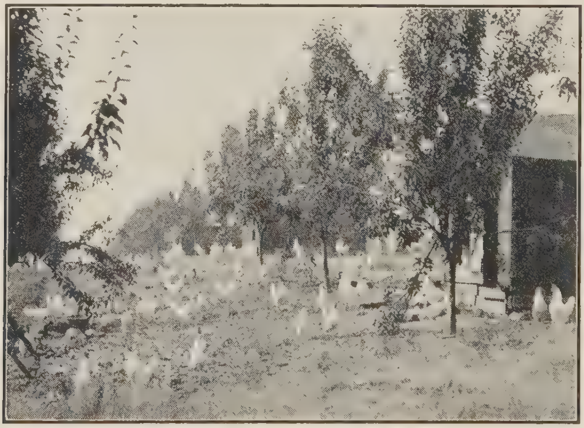

Fig. 86.—Plenty of shade and ample range on clean soil are necessary for best results in rearing high-quality pullets, as shown in this scene from a leading breeder in the state of Washington. (*Photograph by L. C. Beall, Jr.*)

Range Shelters.—In many sections of the country range shelters are used extensively for protection for the growing stock during the summer months. A common form of range shelter used is shown in Fig. 88. They are usually built of sufficient size to be portable and are built of wire netting on the four sides. They are used on many farms and commercial poultry plants where the chicks have been brooded in confinement for about eight weeks and then the range shelters are used.

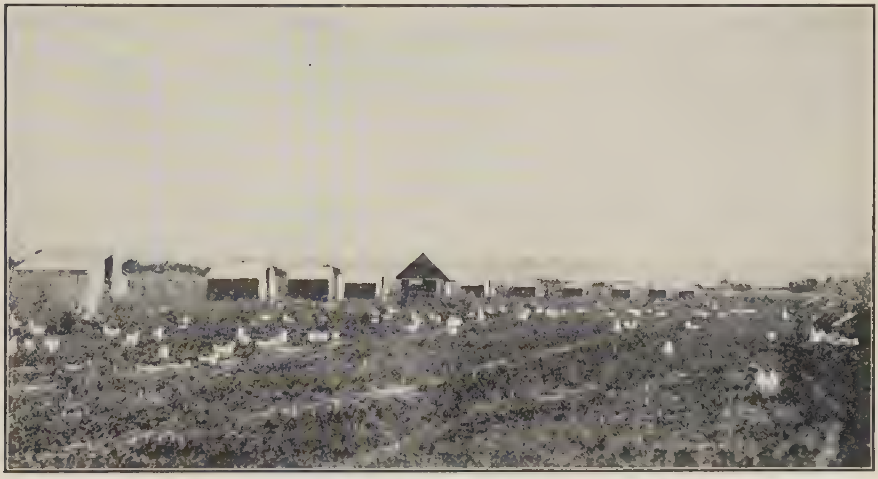

FIG. 87.—Rearing houses widely scattered over an alfalfa field, giving the pullets ample range, on a leading poultry breeder's plant in Idaho. (*Photograph by Archie M. Larson.*)

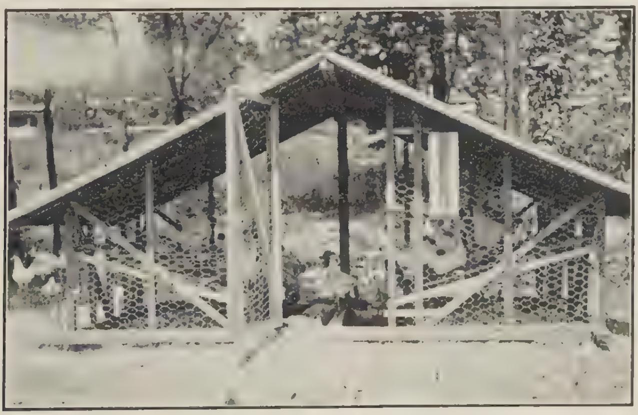

FIG. 88.—Range shelter for growing chicks during the summer months. It provides shade during the daytime and abundance of ventilation at night. The structure is 12 ft. wide by 10 ft. deep. (*Photograph by N. J. Agr. Ext. Service.*)

Separate the Sexes Early.—The cockerels should be separated from the pullets at about eight weeks of age. In the case of Leghorn chicks the separation can be made somewhat earlier. The cockerels may be sold as broilers, kept on a separate range to develop into roasters or they may be caponized. The separation of the sexes at an early age is necessary for two reasons: to provide more roosting and housing room for the pullets and to prevent the cockerels from annoying the pullets. Platt (1929) says: "Provide 35 lin. ft. of roosting space for 100 pullets up to four months of age and 50 ft. after that age."

Proper Growing Conditions.—After the sexes are separated, the pullets should be gone over rigidly from time to time in order to remove any unthrifty ones. The growth of the pullets to maturity should proceed without interruption, because checking the growth at any stage may retard laying at maturity. It has been pointed out previously that egg production contributes the major portion of the total poultry receipts secured from the poultry flock in practically all parts of the country. It is obvious, therefore, that the pullets should be given the best possible growing conditions.

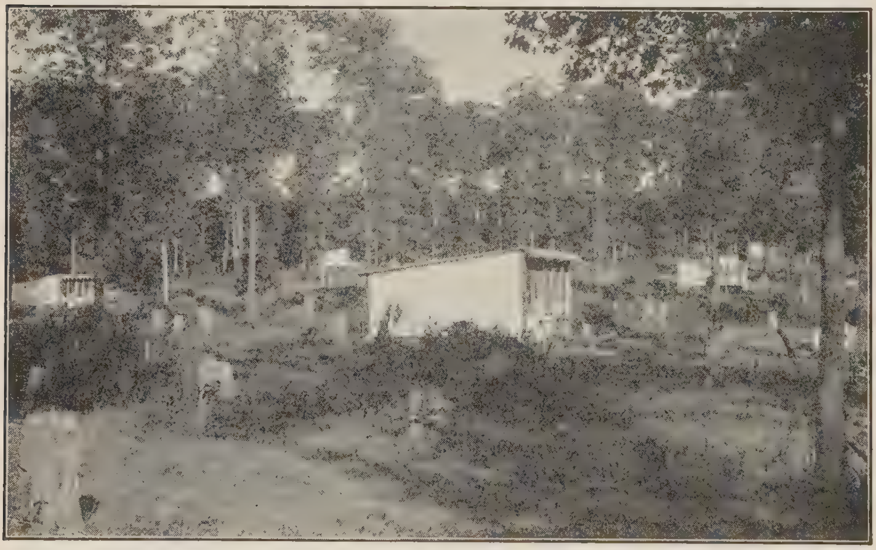

FIG. 89.—Ideal range conditions for young stock at U. S. Animal Husbandry Experiment Farm, Beltsville, Md. (*Photograph by U. S. Dept. Agr.*)

The house in which the pullets are kept should be provided with plenty of ventilation without the houses being drafty. Comfort during the nights is of paramount importance and if the pullets are kept in the houses in which they were brooded, then adequate ventilation by having windows on at least two sides of the house, as shown in Fig. 84, is necessary.

Good range on a grass sod is very effective in providing proper growing conditions. A good grass sod provides sanitation and an abundance of succulent green feed and thus the pullets are kept in the best possible state of health.

Access to grass or other green range and abundance of sunlight are important factors in keeping the pullets in the best possible condition. Growth should be normal and mortality should be as low as possible. At the U. S. Animal Husbandry Experiment Farm at Beltsville, Md., mortality of growing pullets on sod grass has been as low as 5 per cent in a flock of about 7,000 chicks raised.

Rearing conditions for the cockerels, especially when they are kept as breeders, should be such as to promote the best possible growth. The cockerels should be provided with good range shelters or good housing conditions and good range. The cockerels ought to be reared as free as possible from parasites and disease and this can be done best on a clean range of grass sod or other clean range, as shown in Fig. 89.

REARING IN CONFINEMENT

When chicks are brooded in confinement, as discussed in Chapter XV, and are still kept in confinement either in battery brooders or in pens with wire-screen floors, they must be given careful attention. The brooding of chicks in battery brooders and in pens equipped with wire-screen floors is a sanitary precaution against infection from intestinal parasites and disease, such as coccidiosis. When the chicks are carried beyond the brooding stage the same principles apply as emphasized by Charles and Knandel (1928) in Chap. XV.

Avoid Overcrowding.—One of the chief dangers in the rearing of chickens in confinement is the tendency to overcrowd the chickens in the space allotted to them. The sexes should be separated at about eight weeks of age, as in the case of the rearing of chicks on range. The cockerels may be sold as broilers or some of them may be kept as breeders. At any rate, it is necessary to keep both pullets and cockerels under the best of environmental conditions. As the chickens grow they should be separated to other batteries so as to avoid overcrowding. Avoiding overcrowding is of paramount importance in preventing excessive losses.

Plenty of Hopper Space Necessary.—One of the most important things in brooding chickens in confinement is providing plenty of mash hopper space. This tends to prevent restlessness and feather and body picking. Plenty of hopper space is of supreme importance in the rearing of chickens in confinement.

Battery Brooders and Wire-screen Floor Pens versus Range Rearing.—The rearing of chickens in battery brooders and in rooms with wire-screen floors is a problem of economical importance. Rearing chicks on wire-screen floors allows the chickens to take advantage of the benefits of the sun's rays. Also, chicks reared on wire-screen floors usually get more exercise than chicks reared in battery brooders. Where pullets are to be reared to maturity for the purpose of producing eggs, rearing them on wire-screen floors is to be preferred. At the same time, it is realized that when chicks are reared in pens on wire-screen floors it is necessary to provide them with plenty of hopper space in order to prevent as much as possible the bad practice of body and tail picking. Providing plenty of hopper space allows the growing chicks to consume sufficient grain to promote the most efficient growth.

Kennard and Bethke (1929) present a very interesting discussion on keeping chickens in confinement. Because of the importance of the various problems arising in the keeping of chickens in confinement, a part of Kennard's and Bethke's observations are given here:

> With the present information on feeding and management and the proper use of wire-screen sun parlors, does the commercial poultry keeper of today have need for an outdoor range? There is no positive answer as yet, but judging from the experimental evidence available, and the experience of poultry keepers throughout the country, it seems safe to say that the general practice of commercial poultry keepers in the future will be to brood the chicks in confinement and confine the layers and perhaps the breeders. The summer development of pullets may be in confinement, or they may be on a summer range, used exclusively for that purpose. In fact, many progressive poultry keepers are now following this procedure.
>
> As to the farm poultry keepers, the time is near when the majority will likely purchase their pullets ready for summer range, instead of day-old chicks. When these pullets go into laying quarters they will, in most instances, be confined. In the meantime, the farmer who raises 200 chicks or more a year may often succeed better if the chicks are brooded in confinement.
>
> *Sun Parlors and Sun Yards.*—Confined birds may often be benefitted by the outside exposure to direct sunlight even if considerable direct sunlight enters the house, or if the ration carries a potent cod-liver oil. Direct sunlight is the best and most economical source of the vitamin D factor, which is essential for the welfare of the birds. Every effective means, therefore, should be employed for utilizing it to advantage. That is the purpose of the outside sun parlor. It permits getting the birds outside in the direct sunlight without their coming in contact with contaminated soil. This is taking advantage of the best factor afforded by the natural range without incurring its hazards. Where a considerable number of chickens are kept, often the most important function of the natural range is the exposure to direct sunlight it affords the birds. As a source of adequate green feed, it often fails.
>
> The wire-screen sun parlor is an outside inclosure next to the brooder or laying house. It is usually about half the area of the floor inside. The frame for bottom is made of 1 by 4 in. boards set edgewise, and spaced 2 ft. apart. This is covered with ¾ in. square mesh hardware cloth, made of No. 15 or 16 gage wire, 24 or 48 in. wide, the narrow width preferable. This size mesh is satisfactory for both chicks and hens. One-half inch mesh wire is not satisfactory for either. The frames may be made in sections, the size depending upon the number of birds to be accommodated. For a 10 by 12 ft. brooder house, a frame

6 by 8 ft. is used. In case of a sun parlor for layers in a 20 to 24 ft. width poultry house, the frames may be made in sections 8 or 10 ft. wide, and 10 to 12 ft. long. Front and end panels are 24 in. wide, and made of 1 by 3 or 4 in. strips, covered with 1 in. mesh poultry netting. The top panels may be made 2, 3 or 4 ft. wide. The front top panel is hinged so it can be opened easily when desired. If flies are to be excluded, the sun parlor must be enclosed tightly around the bottom and covered with fly screen, instead of 1 in. mesh poultry netting. Of course, the house will then have to be screened against flies. The floor of the screen sun parlor may be placed 10 or 20 in. above ground, so the droppings can be removed by a scraper. Or the frame can be set close to the ground, and removed during the process of cleaning.

To insure that all the birds take advantage of the sun parlor, they should be fed and watered in it, or be driven into it regularly once daily and shut in for a half hour, besides having a chance to go out when they please. If it is desired to feed and water the birds in the sun parlor, the side and front panels can be slatted with plaster lath so they can reach through to feed and water outside the inclosure. The mash troughs are protected from rain by slanted boards, hinged so as to turn up when feed is being put into troughs.

A sun yard is an outside yard, inclosed the same as the sun parlor, but instead of the screen floor, the ground is covered with 8 to 12 in. of cinders, slag, or crushed stone to prevent the birds from coming in contact with the soil. The material used should be coarse enough so as to permit the rain to filter through readily, and, at the same time carry away the soluble part of the droppings. The difficulty with this plan is that the filling material will likely need to be removed and renewed yearly. Some poultrymen cement the bottom of sun yards, but a cement yard is not satisfactory in that it is supposed to be washed, scrubbed, and disinfected daily, which is seldom done. Furthermore, the cement yard may require the use of litter to prevent the birds from contracting the habit of eating the droppings.

Both Sides of Confinement.—Although keeping chickens in confinement has many undeniable advantages, and offers the only effective solution of many problems and difficulties, especially for the commercial poultry keeper, or the farm poultry keeper whose flock is seriously troubled with disease and internal parasites, the disadvantages of keeping chickens in confinement should not be overlooked.

To begin with, the brooding of chicks and development of pullets in confinement, require more exact feeding and management. The chicks or pullets must have a complete ration, in spite of this, they will be more subject to the vices of feather eating and cannibalism, which are probably the greatest disadvantage and liability to be encountered when one undertakes to keep chickens of any age in confinement. However, the prevention and control of these vices is a matter of proper management, or knowing what to do and how to do at the right time, an accomplishment which must be learned largely by experience.

A Practical Plan.—A good plan is to secure pullets ready for summer range, or brood the chicks indoors, develop the pullets on range used exclusively for that purpose. Then confine the pullets when they are ready to lay to wire sun parlors or sun yards, so they will not come in contact with the soil. The pullet range then would never be contaminated by mature birds. It would have part of the year to become reconditioned. The range should be large enough so the housing quarters can be moved to different sections so as not to use the same area two years in succession.

By use of suitable summer range shelters and the feeding of the birds some distance from the roosting quarters, the droppings will be distributed over a wide area and no part of the range should become bare and dangerously contaminated. This can be effectively accomplished by moving the range shelters, which is a simple matter; and gradually moving the feed and water away from roosting quarters 10 to 20 ft. daily, until the pullets spend practically all the day 500 to 1,500 ft. away from the roosting quarters, and return to roost at night. This plan carefully followed, and if at the same time, the other essential requirements have been met, should in most cases yield pullets ready to lay in the fall and comparatively free from disease and parasites.

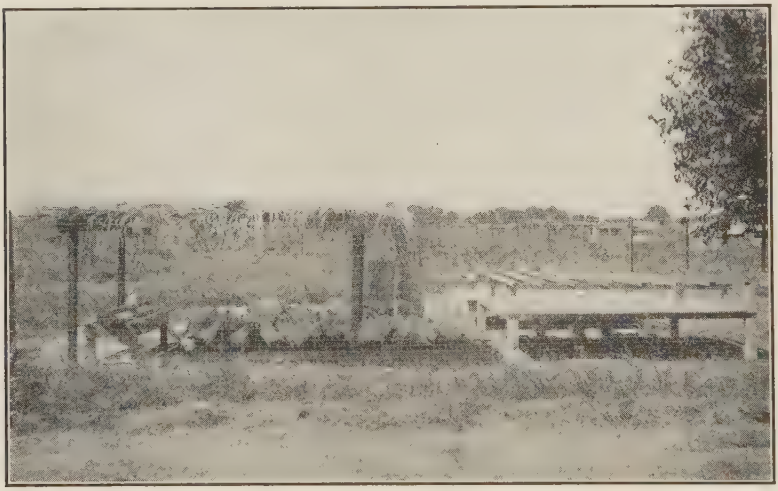

FIG. 90.—Providing adequate shade during the daytime is very important in certain sections of the Southwest where overhead protection at night is not so important. Scene at the U. S. Poultry Experiment Station at Glendale, Ariz. (*Photograph by U. S. Dept. Agr.*)

This plan of management should simplify present range problems and difficulties. Perhaps the most important advantage of the plan is that the range would never be frequented by mature birds, which are often the most dangerous carriers of disease and intestinal parasites. Is there a more simple and effective solution of the range problem for the farm poultry keeper?

Finally, the question is yet to be answered, shall the chickens be confined? It seems there may be two answers: Yes, for commercial poultry keepers, because there is hardly any alternative for them if they are to make the chicken business a profitable, large-scale commercial enterprise. Yes and no, for the farm poultry keeper. If serious trouble is being experienced with coccidiosis, tuberculosis, or intestinal parasites, or other difficulties arising from a contaminated range, and if the poultryman is in position to feed and manage the birds in accordance with their more exacting requirements when confined, then it may prove the most effective solution of his difficulties. On the other hand, since there are certain difficulties and disadvantages attending confinement of chickens, the farm poultry keeper who is succeeding with brooding the chicks, and developing the pullets on the range, and even permitting the layers to run at large, would have little, if anything, to gain, and perhaps much to lose by confining them.

CHAPTER XVII

BROILER PRODUCTION

The development of the broiler industry represents one of the phases revealing the extent to which the poultry of the United States has become specialized during recent years. In the early development of the poultry industry fresh poultry was ordinarily available from the fall of the year to the latter part of January. It is natural to expect, therefore, that a specialized industry would be developed whereby fresh dressed chickens would be made available to consumers during the time that other forms of fresh chickens are not available. The production of broilers has filled this need.

Up to a few years ago the most profitable broiler season lasted from January to June, inclusive, but in recent years the season has been shortened considerably, largely because it is now possible to hatch and rear chicks during the winter months, with the result that fryers and roasters are marketed earlier in the season than was formerly the case. The development of the broiler industry has resulted largely from improved practices in the rearing of chicks in confinement, as discussed in the preceding chapter and in the chapter on Feeding Practices.

It has been determined, as explained in the chapter on Nutrition, that the greatest increase in growth (flesh production in the sense of the discussion in this chapter) is in the inverse proportion to the amount of feed consumed, or, in other words, that the greatest gains in relation to the amount of feed consumed are made in the first few weeks. The data in Table 43 bring this point out quite clearly. Further information is available in the chapter on the Economics of Production and Marketing.

TABLE 43.—APPROXIMATE POUNDS OF FEED REQUIRED TO PRODUCE ONE POUND GAIN IN WEIGHT IN RHODE ISLAND RED MALE CHICKENS[1]

Age in weeks	Approximate weight per bird, pounds	Approximate pounds feed consumed per bird	Approximate pounds feed per pound gain in weight
10 to 12	2	6	3
14 to 15	3	11	3⅔
17 to 18	4	18	4½
20 to 21	5	25	5
24 to 25	6	36	6

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[1] Data with modifications by S. L. Althouse, *Poultry Item*, vol. 32, No. 3, pp. 10, 88–89.

The data in Table 43 show that the longer chickens are kept the more the amount of feed required to produce one pound of gain in flesh production. The figures are only approximations because actual results secured depend upon a variety of factors, including the kind of chickens, the kind of ration fed and general methods of management. The proportion of the sexes is also a factor because males grow faster than females. Further information on the growth of chickens in relation to feed consumption is given in the chapter on Economics of Production and Marketing.

Kind of Chicks.—Among the numerous breeds of chickens, those most commonly used for broiler production include Plymouth Rocks, Rhode Island Reds and Wyandottes. Cross-bred chickens are used extensively because it has been found that cross-breeding produces chicks that have abundance of constitutional vigor and tend to grow rapidly. Barred Plymouth Rock males mated to White Wyandotte females make a popular cross, since the broilers at marketing time are all barred, this being a factor of importance in marketing broilers alive on the New York City market. When Barred Plymouth females are mated to Rhode Island Red males, the chicks can be separated according to sex at hatching time, as explained on page 109, where other sex-linked crosses are also discussed. In commercial poultry-raising sections of the country, where White Leghorns nearly always predominate, White Leghorn cockerels are sold as broilers.

Broiler Prices.—The most profitable broiler-producing season is usually from January to June, inclusive, because that is the season of highest prices paid for broilers, as shown in Tables 44 and 45. It is true, of course, that prices of hatching eggs are higher in January and February than in May and June, but it is also true that the higher prices received for broilers more than offset the higher prices paid for hatching eggs.

The fact is appreciated, of course, that broiler prices fluctuate considerably from year to year but the data in Tables 44 and 45 serve to show the general relationship that exists between prices received during January to June, inclusive, as compared with the rest of the year, as well as the general relation in prices among frozen, fresh western and near-by (produced within a short shipping distance of the New York market) broilers.

Broiler Production Problems.—During recent years broilers have been reared for the most part in battery brooders as well as in pens with and without hardware cloth bottoms. Methods of brooding and rearing are discussed in the two preceding chapters. Methods of feeding broilers are discussed in the chapter on Feeding Practices.

Broiler plants where several thousand broilers are produced annually have been in successful operation for a number of years, especially in the northeastern section of the United States, as explained by Richards, Abell and Rinear (1928). Among the more important problems in the successful management of a broiler plant are proper temperature, a certain amount of humidity to prevent the feathers from becoming too dry, avoiding overcrowding the chicks and providing plenty of mash hoppers for feeding. These and other problems are discussed in appropriate places in this book.

A recent development in the broiler industry on the Pacific Coast and elsewhere is the canning of the broilers as soon as they have reached market size. The canning of chickens is discussed in the chapter on Marketing Chickens.

TABLE 44.—MONTHLY AVERAGE PRICES FROM PRODUCER'S PRICE CURRENT.
AVERAGE PRICES OF INSIDE AND OUTSIDE DAILY NEW YORK QUOTATIONS.[1]
BOX PACKED WESTERN BROILERS

(This is a medium grade of western receipts. The true relation between frozen western, fresh western and near-by dressed can be seen by referring to the next table)

	Frozen[2]				Fresh			Fryers	Roasters		
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
1914	. . . . .	23.00	22.42	19.35	. . . . .	28.92	21.21	17.38	18.28	17.28	16.78
1915	. . . . .	23.50	23.50	23.50	32.45	26.21	22.65	17.94	19.58	19.08	17.77
1916	24.00	24.00	24.59	25.36	31.50	28.85	26.60	27.06	25.21	24.24	23.53
1917	27.00	27.00	23.87	24.50	. . . . .	28.61	25.28	22.73	28.31	26.52	25.06
1918	32.50	32.02	36.08	38.37	. . . . .	47.17	45.46	38.43	35.04	33.00	33.61
1919	. . . . .	42.00	44.88	45.23	55.31	48.46	42.27	36.89	37.06	33.62	33.26
1920	. . . . .	45.50	45.24	45.00	. . . . .	58.35	57.92	42.77	45.42	39.40	36.73
1921	51.70	46.50	45.17	40.90	54.40	42.08	37.98	36.30	37.00	31.48	31.15
1922	. . . . .	35.81	34.56	35.00	50.64	46.23	38.40	32.81	33.12	31.02	29.31
1923	35.71	36.00	35.56	35.00	49.67	45.85	41.26	34.90	32.33	31.40	28.33
1924	37.00	36.70	38.27	38.00	47.74	39.78	38.06	40.25	40.66	35.08	32.93
1925	37.50	36.30	36.00	34.90	42.90	39.00	33.19	28.98	34.12	33.42	31.15
1926	38.06	38.07	38.13	39.04	45.38	44.06	37.71	34.02	34.20	33.82	30.08
1927	38.72	36.59	30.98	27.94	34.90	31.12	28.11	28.05	31.06	30.98	28.81
1928	35.74	36.15	35.93	35.26	43.04	36.87	35.82	35.31	39.60	35.42	33.88
Av. 15 years...	. . . . .	34.61	34.34	33.82							
Fresh basis....	. . . . .	44.61	44.34	43.82	44.36	39.43	33.46	31.59	32.73	30.45	28.82

[1] Data by S. L. Althouse, *Poultry Item*, Vol. 32, No. 3, pp. 10, 88–89.

[2] Prices on fresh are not given for these early months because, up until four years ago, there were so few broilers in the market from January to April that in many cases there were no quotations except for stags and roasters and this is no fair comparison. By referring to the Table 45 it will be seen that fresh western for 1928 (in fact, for the past four years) have averaged about 10 cents per pound higher than frozen. An average of 10 cents should be added to the above frozen figures to make them comparable to the fresh figures for May, June and July.

TABLE 45.—RELATION BETWEEN FROZEN WESTERN, FRESH WESTERN AND NEAR-BY DRESSED BROILER PRICES FOR 1928

	Mo. av. frozen western broilers	Mo. av. fresh western broilers	Top quotation best near-by broilers, cents
January	35.74	28.74	30
February	36.15	50.96*	30 up to 60
March	35.93	45	50 to 55
April	35.26	46.32	50 to 55
May	.....	43.04	55 down to 45
June	.....	33.87	45 down to 43
July	.....	35.82	41
August	.....	36.39	41 to 43
September	.....	37	43
October	.....	36.83	43 to 38
November	.....	36.50	38 to 36
December	.....	36.10	36 to 33

* In 1928 the peak was reached unusually early (February).

CHAPTER XVIII

CAPON PRODUCTION

In many of the larger cities there are good markets for large roasting chickens. The largest size for roasting is obtained when the cockerels of certain breeds are castrated. A castrated chicken is known as a "capon" and since capons attain their maximum size when from about eight to ten months of age, they are ready for market after the Christmas holidays, when other forms of fresh-killed young poultry are scarce. Capons retain the tenderness of the meat characteristic of young cockerels. Some poultrymen hatch chicks in December and January so that their capons are ready for the Thanksgiving and Christmas markets.

Breeds for Caponizing.—A very complete description of caponizing is given by Black (1926), a portion of which is given here. A special set of instruments is necessary for caponizing and several different makes are made by manufacturers.

The largest capons are obtained from Jersey Black Giants, Langshans, Cochins and Brahmas. These breeds, however, are slow to mature and will hardly develop in time for the holiday season unless hatched early. In New Jersey, large numbers of Jersey Black Giants are caponized and these are marketed usually from Christmas to Easter. Good prices are obtained at this season, and the breed has become very popular on many general farms. Plymouth Rocks, Rhode Island Reds, Wyandottes and Orpingtons make excellent capons and can be brought to prime condition in seven to ten months. With all ventures in meat production, it is essential that the birds be grown quickly and marketed as soon as they reach the desired weight and condition.

Age to Caponize.—Strong, vigorous cockerels should be selected and the operation should be performed before there is much sign of comb development. Birds from 1½ to 2½ lb. in weight or from 8 to 12 weeks of age are about the proper size. They should be placed in clean crates without litter and kept in a comfortable place without water or feed for a period of 12 to 24 hours. This starvation period is all important, for the operation is most easily performed on properly starved birds and there is much less bleeding.

How to Caponize.—If possible, caponizing should be done on a bright, sunny day. For the convenience of the operator, choose a sheltered spot where unlimited sunshine is available. Set up a barrel or a couple of egg cases as a table on which to work. A crate containing the cockerels should be close at hand and another empty crate should be provided to receive the cockerels after the operation.

The cockerel should be fastened to the caponizing board by means of the straps, one strap being placed around the wings close to the body, the end drawn through the ring and the strap fastened to the board by means of the slots and the screw eye. The other strap should be placed around the legs above the hock joint and, after the bird is drawn taut, should be fastened in the suitable slot. In securing the bird to the board, the left side should be next to the board and the right side of the bird facing the operator. Since the incision is made between the last two ribs of the bird, pluck a few feathers from this region, thus exposing these ribs. Wet this area with a little of the solution from the pan and soak the surrounding feathers thoroughly so that they are held back out of the operator's way.

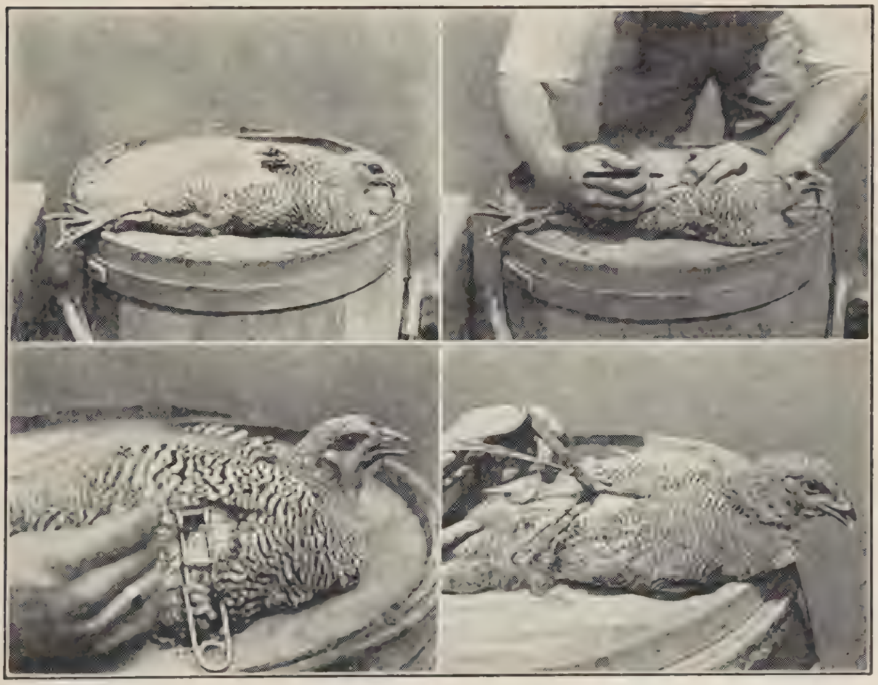

FIG. 91.—Upper left, the cockerel in position for caponizing, with feathers removed for making the incision.
FIG. 92.—Upper right, making the incision.
FIG. 93.—Lower left, the spreaders inserted and a probe inserted to locate the testes
FIG. 94.—Lower right, removing the testes. (*Photographs by U. S. Dept. Agr.*)

In making the incision, hold the knife firmly between the thumb and forefinger, allowing only about one-fourth inch of the blade to be exposed. Held in this manner, it is hardly possible to cut so deeply that the intestines are injured. With the fore-finger of the left hand, locate the last two ribs which lie just in front of the hip joint. Draw the skin back toward the hip and place the knife between the ribs approximately one-half to three-quarters of an inch below the back bone. Now make an incision about one inch long by drawing the knife toward you, being careful to follow the curve of the ribs. The spreader should then be inserted and the incision opened as far as possible without tearing the flesh. With the tearing hook, tear the thin membranes which cover the intestines, but carefully avoid hooking the intestines. The upper testicle can then be observed lying just below the front end of the kidney and close to the backbone. In birds of proper size, the testicle will be about the size of a grain of wheat and usually deep yellow, although at times the color may be gray or even black. The lower organ lies just underneath the upper and may be seen by raising the upper with the probe. A large artery will be observed running between the two; should this be punctured during the removal of the organs, death will result. With the jaws of the removers slightly open, reach underneath the lower testicle and gently move the instrument upward, allowing the organ to slip between the open jaws. Being sure that the entire organ is within the remover and that no blood vessels have been grasped, slowly pull the instrument out of the body cavity with a twisting motion until the organ is severed from the body. Next, remove the upper testicle in a similar manner. Should difficulty be encountered in attempting to remove both organs from one side, the upper one should be removed and the bird turned over and operated on from the left side. It is essential that the organs be removed intact, for if the wall of the testicle is ruptured and a portion allowed to remain in the body cavity, a "slip" will result. Since a "slip" has neither the good qualities of the capon nor the reproductive qualities of the rooster, it is important that every precaution be taken to avoid it.

CHAPTER XIX

HOUSING PRINCIPLES AND PRACTICE

The proper housing of chickens is of fundamental importance in affecting results secured, whether it be in the growth of chicks or in egg production in pullets and hens. The function of housing is to provide protection from winds, storms and excessive changes in temperature. The wild fowl roosted in the trees and the chicks were reared in the open, and, as long as life was sustained and the species reproduced its kind, there was little need for artificial protection. But modern conditions of poultry keeping demand relatively rapid growth in the chicks and relatively high egg production in hens. It is essential, therefore, that chickens must be kept comfortable at all stages of practice in modern poultry husbandry and the manner in which they are housed determines to a material extent the results secured. Also, since the housing of chickens constitutes one of the more important cost factors in poultry husbandry operations, the cost of housing should be given every consideration.

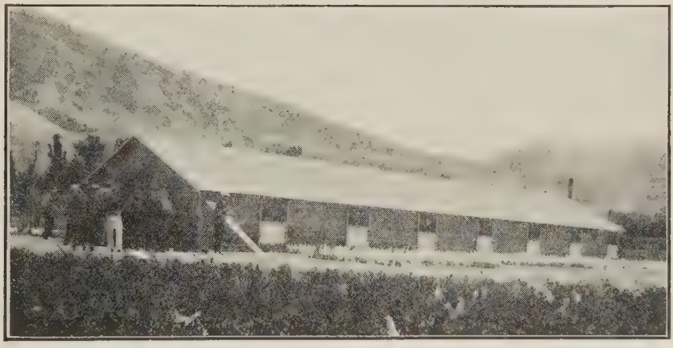

FIG. 95.—Type of brooder house, on Mr. Cosgrave's farm, commonly used with hot-water heaters in Utah. (*Photograph by Utah Coll. Agr.*)

Essentials in Housing Chickens.—The fundamental features involved in housing chickens include: (1) providing comfort, (2) economy, (3) convenience. These three features are discussed by Jull and Lee (1928*b*) in the following manner:

> The first essential in housing chicks or laying hens is comfort, for unless chicks are comfortable they will not grow well and pullets and hens will not lay well. To be comfortable a house must provide plenty of room, be well supplied with fresh air and sunlight, and always be dry.

The second essential is economy. A new house need not be expensive, but it should be durable; the more durable the house the less the cost of housing per year in a period of years. Avoid building cheap, flimsy houses, because they soon have to be replaced.

The third essential is convenience. The house should be conveniently located and should be of such shape and size that work in it can be done with ease. Too often the mistake of building small houses with low roofs is made, so that it is drudgery to care for the chicks or the layers. Since labor is an important factor in the management of poultry, the arrangement of the house for convenience adds greatly to the chances of success.

BROODER HOUSES

A discussion of brooding principles and practice would not be complete without a discussion of the houses in which the brooders are used. However efficient the brooding system may be, it is obvious that the houses in which chicks are brooded and reared should be built so as to promote the best growth in the chicks.

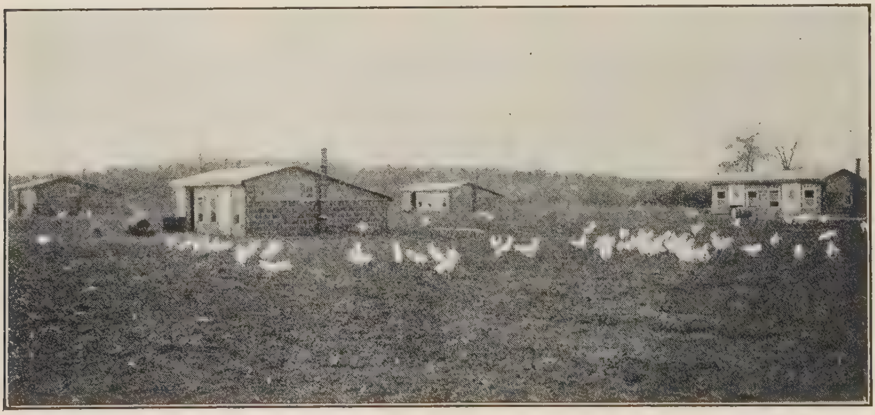

Fig. 96.—Brooder houses on a New Jersey poultry plant located sufficiently far apart to give the rearing stock good range and to avoid soil contamination. (*Photograph by Willgerodt Bros.*)

The brooder house should be built sufficiently large to accommodate the unit of chicks to be brooded. The house should also be built so as to conserve heat and, at the same time, provide adequate ventilation during warm weather. Drafts should be avoided. It is obvious that such widely separated states as Alabama, Massachusetts and Montana require somewhat different types of brooder houses, although in fundamental features they should be in agreement.

For a unit of 300 chicks, which is as many as should be brooded together if mortality is to be kept at the minimum and optimum growth obtained, there should be approximately 150 sq. ft. of floor space in the house. Where the chicks are brooded on range, the house should be portable in order that it may be moved to clean ground each year.

Where chicks are brooded indoors or where they are brooded under conditions of confinement, it is necessary to take precautions against the development of leg weakness, due to a lack of proper bone development. Among other things, it has been determined that ordinary window glass does not allow ultra-violet rays to pass through it, with the result that chicks raised under confinement under ordinary window glass frequently develop leg weakness. During recent years there have been placed on the market a number of "glass substitutes" which are advertised to allow ultra-violet rays to pass through them. The relative value of "glass substitutes" in preventing rickets in growing chicks is discussed in Chap. XXIII.

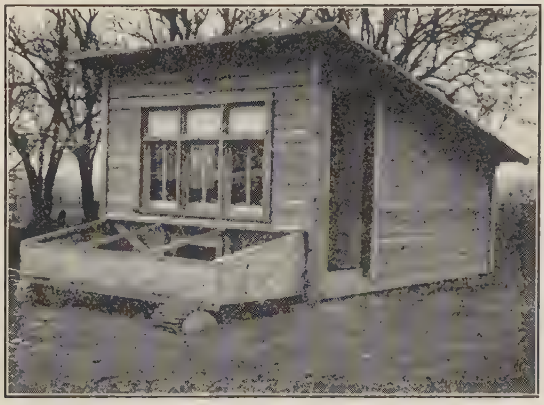

Fig. 97.—A shed-roof brooder house, 10 by 12 ft., with an attached sun porch, 10 by 3 ft., suitable for Nebraska. *(Photograph by Neb. Coll. Arg.)*

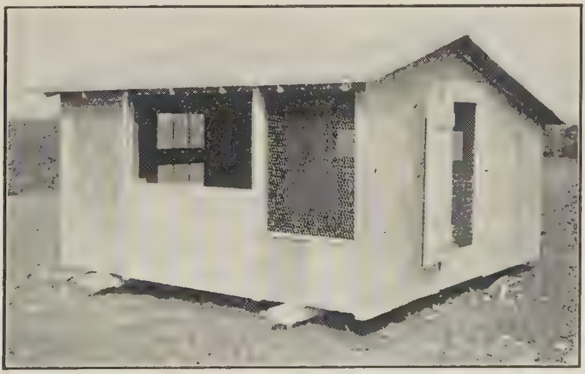

Fig. 98.—A 12 by 12 ft. colony brooder house recommended for use in Connecticut, equipped with cel-o-glass windows which swing inward. *(Photograph by Acetol Products, Inc.)*

For the most part, the construction of brooder houses involves the same fundamental principles as in the construction of laying house, discussed in the following pages.

Illustrations of brooder houses suitable for different sections are shown in Figs. 95, 96, 97 and 98. Detailed plans of colony brooder houses suitable for use in any state may be obtained from the poultry department of the state colleges of agriculture, a list of which is given on page 572. Detailed plans of continuous brooder houses for brooding several hundred or several thousand chicks may be obtained from the manufacturers of continuous brooding systems.

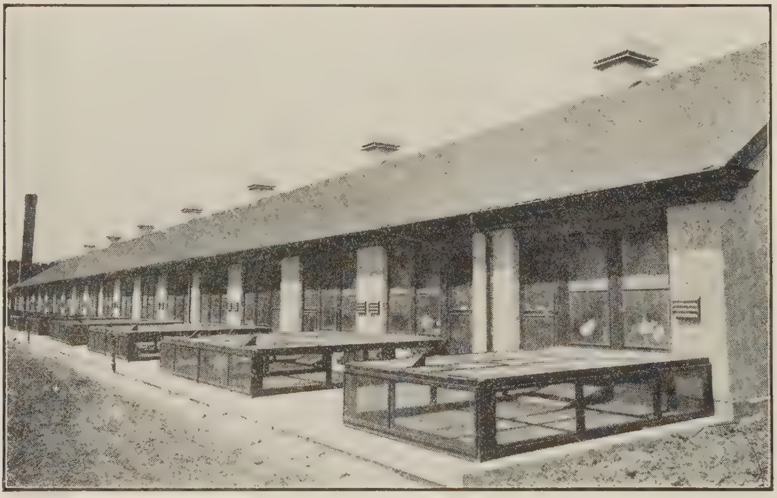

FIG. 99.—A continuous brooder house, with wire-screened sun porches on a concrete slab along the front of the house, at State College, Pa. (*Photograph by Pa. State Coll. Agr.*)

LAYING HOUSES

The most important principle in housing laying pullets and hens is that they be provided with the most comfortable living quarters during the fall and winter months. It is at this season of the year that the greatest profits are made in egg production if the laying stock lays well. This is the time of year that egg prices are relatively the highest and so from a practical standpoint it is very desirable to secure good egg production, particularly since the major portion of the total poultry receipts, as discussed on pages 131 and 502, are obtained from eggs.

In the southern parts of the United States the problem of providing comfort in housing during the fall and winter months is not a serious problem because the weather is fairly mild throughout the winter season. In the northern sections of the country, however, climatic conditions during the fall and winter months are liable to be quite changeable and unless the layers are kept under optimum conditions, the results secured will not be in keeping with the costs of operation.

The Ventilation of Laying Houses.—The proper ventilation of the laying house is of the greatest importance in providing comfort for the layers during the fall and winter months as well as during the hot summer months. Providing a comfortable house during the summer months is a fairly simple matter, provided the house is kept sufficiently open to allow free circulation of air in all parts. In order to provide extra ventilation in hot weather an adjustable ventilator opening should be made in the rear of the house, between the plate and the eaves, but it should be made so that it closes tight in cold weather.

Dampness Dangerous.—Dampness in the laying house during the winter months in northern latitudes has long been regarded as the most serious obstacle in avoiding colds, roup and other diseases as well as in keeping the layers in good laying condition. Dann (1923) found that the following amounts of water were produced in one day by 100 Leghorn hens, weighing 373 pounds:

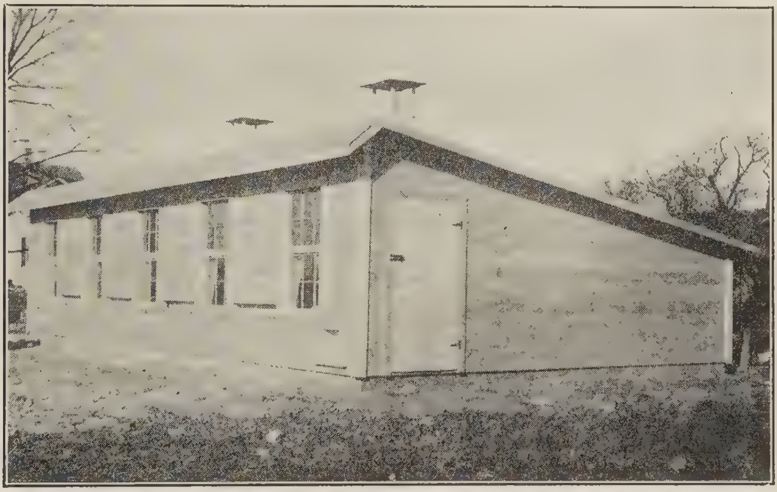

Fig. 100.—The Michigan shed-roof type of laying house, 18 by 20 ft., with ventilators. (*Photograph by Mich. Agr. Ext. Service.*)

	Total Weight, Pounds
Excreta	37.108
Water in excreta when dropped	21.298
Water retained in air dry excreta	2.530
Water to be evaporated from excreta	18.768
Water spilled into litter by drinking	0.927
Water to be evaporated from litter	19.695
Water given off through respiration system	8.652
Water to be removed from poultry house	28.347

Dann points out that when 100 Leghorn hens were on the roosts 10 hr. and on the floor 14 hr. daily, there were 7.820 lb. of water evaporated from the droppings boards and 11.875 lb. of water evaporated from the floor litter.

The effect of dampness in the poultry house on egg production has been reviewed by Lee (1929), whose observations are included in this discussion, together with numerous additions. In cold weather, when the body heat of the birds is conserved, the humidity in the house tends to become excessive and becomes apparent when deposited as frost on the rafters and ceiling of the house in cold weather. It also becomes apparent when the litter on the floor is very damp. Since poultry do not have sweat glands, a large amount of moisture is given off in their breath.

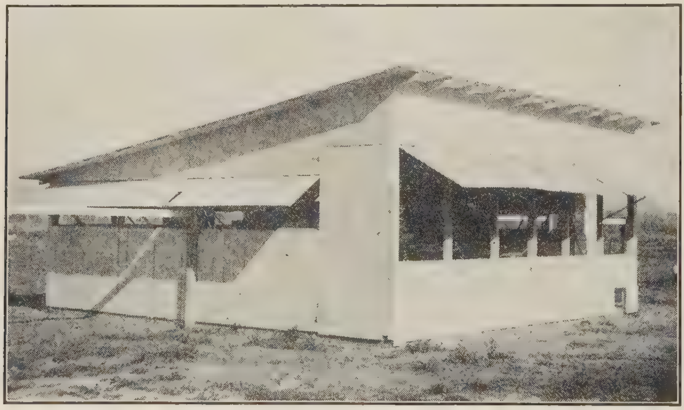

Fig. 101.—A well-ventilated laying house at the U. S. Poultry Experiment Station at Glendale, Ariz. (*Photograph by U. S. Dept. Agr.*)

Air Requirements Relatively Large.—According to King (1914), hens weighing 3 lb. use 24.8 cu. ft. of air per hen daily. That the hen in breathing utilizes about three times as much air per pound of live weight as does the cow is shown in the following data by Calin, quoted by King. The number of cubic feet of air breathed every 24 hr. per thousand pounds of live weight was found to be as follows:

Cow	2,804
Man	2,833
Horse	3,401
Hen	8,278

As a result of experiments conducted at the Southeastern Agricultural College, Wye, England, it was concluded that fowls breathe about a pint of air per minute or 1.2 cu. ft. per hour. It was estimated that 35 to 40 cu. ft. of air for each bird was necessary to keep the air pure and that 9 volumes of carbon dioxide in 10,000 parts of air was the greatest permissible air displacement. The air requirements of small and large fowls were found to be about the same. In these experiments a high carbon dioxide content in the air caused the production of eggs which were infertile. The use of 10 cu. ft. of space per fowl is recommended.

Humidity in Houses.—The Washington Experiment Station (1925) reported no difference in the winter, especially in cold weather, in the relative humidity of two houses, one with and one without a straw loft. The straw loft averaged about 12 per cent moisture content and apparently the straw in the loft did not absorb any moisture from the litter. Considerable moisture settled in the floor litter of the straw-loft pen. At the Ontario Agricultural College, Graham has been using cotton muslin stretched from plate and plate, forming the ceiling of the laying pen. This arrangement is used instead of straw and gives satisfaction; it has the advantage of being free from both rats and dust. The Iowa Experiment Station (1926) reported poultry-house experiments in which no correlation between humidity or air supply and egg production, fertility or hatchability could be found. Moisture conditions, which would ordinarily be considered very bad in a poultry house, apparently had no detrimental effect on the hens.

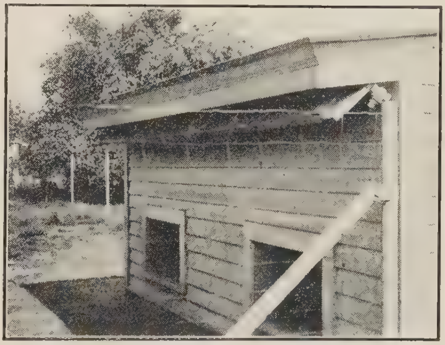

FIG. 102.—Showing rear ventilator under the eaves, and windows at the rear under the droppings board. *(Photograph by Ill. Coll. Agr.)*

The Nebraska Experiment Station (1924), using a hair hygrometer in a tight house, found that the relative humidity was materially reduced when the house was heated. The relative humidity varied inversely with the temperature, but a wide range in humidity did not appear to affect egg production. These houses were closed and sealed tightly at 4 p.m. and not opened until 7 a.m. Practically the same egg production was secured from such houses as from those well ventilated, although in the sealed houses the carbon dioxide rose to as high as 58 and 70 parts in 10,000 parts of air.

Mechanics of Ventilation.—The problem of the mechanics of ventilation of laying houses has been discussed by Lee (1929) along the following lines: The general style of house with the combination of windows and curtained openings, developed by the Maine Experiment Station about 1903, is probably the type used most extensively throughout the country. The New Jersey Experiment Station compared several types of houses and reported best results from a shed-roof house with a combination of glass and muslin in the front. The factors studied were cost, dryness, warmth in winter and coolness in summer. In houses with this type of front about 1 sq. ft. of muslin is used to from 10 to 15 sq. ft. of floor space or 1 to 8 to 10 sq. ft., depending upon the depth of the house. The Missouri Experiment Station at Mountain Grove secured the best results from 1 sq. ft. of muslin to 15 sq. ft. of floor space in a house 15 ft. deep, 1 for 20 sq. ft. in a house 10 ft. deep and 1 for 10 sq. ft. in a house 20 ft. deep.

Ventilating by Windows.—Windows are used in many sections of the country primarily for lighting purposes, but they are made adjustable in order to provide for ventilation. The amount of glass used is variable but about 1 sq. ft. of glass is used for 15 sq. ft. of floor space. Jones and Card (1915) recommend 1 sq. ft. of glass to each 12 sq. ft. of floor space. Ventilation is secured almost entirely by regulating the windows, curtains and doors according to the weather conditions. Most houses have a window in the rear wall under the dropping board, which is used for ventilation as well as for light. Glass substitutes instead of glass are coming into general use, especially for rearing chicks in confinement and when laying hens are kept confined. The value of a glass substitute depends upon its ability to transmit the ultra-violet rays of light, as discussed on pages 359 to 361.

A shed-roof house 20 ft. deep which has a front about 8 ft. high makes a very good poultry house, while with a combination roof a building 7 ft. high in front and 9 ft. at the ridge also makes a good poultry house. The height of poultry houses is arranged largely to provide good lighting conditions and for the convenience of the attendant, as a house for hens would need to be only about 18 in. high in order to provide as much air space as is allowed for other classes of live stock, namely 1 cu. ft. of space per pound of live weight.

Muslin curtains are used extensively for ventilation and are fairly satisfactory in cold weather if kept clean and dry but provide little ventilation when wet. Slatted wind bafflers are used in place of muslin curtains in some houses but can not be opened in good weather as are the curtains.

The modified King or similar systems of ventilation which involve the use of controlled openings and ventilating ducts are now being used in many modern poultry houses of large capacity.

The Problem of Temperature in Laying Houses.—The effect of the number of heat units given off by laying hens and the heating of laying houses artificially have been examined by a number of investigators. Kelley (1927) observes that

> Under average conditions, a chicken gives off heat from its body to the extent of 5½ heat units, B.t.u. (British thermal units, the standard measurement of heat units) per pound of its weight, per hour. Taking the average weight as

four (4) pounds, the heat developed by 100 chickens would be 5½ × 4 × 100 = 2,200 heat units per hour.

It appears however, that tests from which this figure was obtained were conducted with the temperature of the surrounding air at a temperature of probably 65° F. In winter, the heat given off must be considerably more, because the difference between the body temperature and the temperature of the surrounding air is greater.

The heat given off will not be directly proportional to this temperature difference, however, because body insulation is increased in winter by closer feathering. Estimating the effect of the latter factor at 30 per cent, the heat given off when the temperature of the surrounding air is 32° F., would be

$$\frac{(105^\circ\text{ F. body temp.} - 32^\circ\text{ F.})}{(105^\circ\text{ F.} - 65^\circ\text{ F.}) \times 130\text{ per cent}} \times 2{,}200 = 3{,}080 \text{ heat units per hour from 100 chickens.}$$

Heating Laying Houses.—The effect of heating laying houses has been discussed by Lee (1929), the following remarks being a summary of his observations:

Artificial heat, used with poor results a number of years ago, is again being used in some places with better ventilation than was used previously and with much better results. The North Dakota Experiment Station (1896) reported egg production greatly increased and food consumption decreased in heated houses. The Montana Experiment Station (1902) reported that houses may be profitably heated to a temperature of from 45 to 50 degrees. The Nebraska Experiment Station (1924) secured increased egg production in heated houses. The Wyoming Experiment Station (1927) reported that a house insulated to conserve heat gave better egg production than one not insulated. The use of curtains in the front of open-front houses, double walls for the rear, roof and ends of poultry houses, straw lofts and the construction of houses 20 ft. or more deep, all represent efforts to conserve heat in poultry houses. The Kansas Experiment Station reports that a straw-loft house was warmer in winter and cooler in summer than a shed-roof house. The Wyoming Experiment Station (1927) secured the best egg production and greatest profit from straw-loft houses. The heating of deep poultry houses appears to be advantageous, particularly when used to avoid sudden changes in temperature, but considerable work is still needed to determine the manner in which heat can be supplied most profitably.

During recent years the practice of laying heating pipes under the floor of the laying house has been on the increase, sometimes motors being used to force the circulation of the water through the pipes. In this way the litter is kept dry and the floors are kept comfortable even in the coldest weather. Where the pipes are laid under concrete floors, the pipes themselves should be laid in sand in order to allow expansion of the pipes when the water in them is heated. Other houses are sometimes heated with pipes running along the rear of the house, under the droppings boards.

The Location of the Laying House.—The comfort that the layers derive from their house is determined to a considerable extent by its location. The house should not be located in a hollow where the soil can not be drained and where cold air settles. Well-drained land and good circulation of air, without excessive exposure, are two essentials in keeping the layers comfortable, whether in the house or outside.

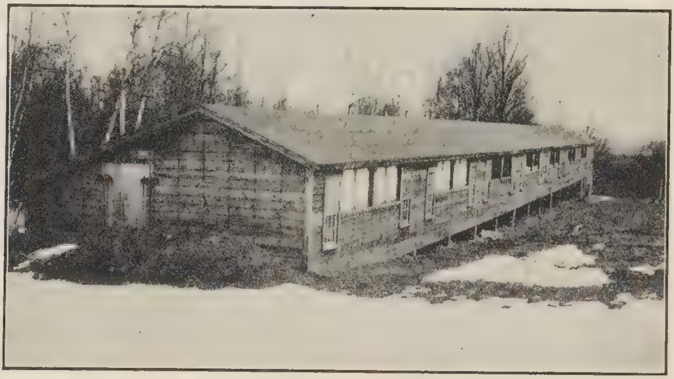

Fig. 103.—A continuous laying house in Massachussetts. (*Photograph by Wm. C. Monahan.*)

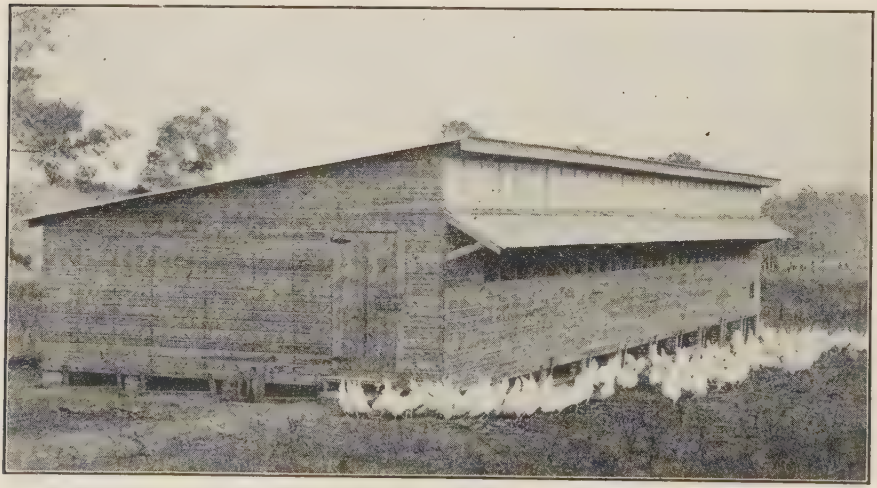

Fig. 104.—A laying house on the farm of Mrs. A. R. Bryan, built according to the plans of the Louisana Agricultural Extension Service. (*Photograph by La. Agr. Ext. Service.*)

Desirable Soil.—Where a laying house is being built on one's own place there may be little choice regarding the character of the soil in relation to its suitability for poultry raising. Where one is going into the poultry business, however, the character of the soil should be taken into consideration. A light loam which will grow grass and crops well and, at the same time, is readily drained is probably the best type of soil for poultry. A very heavy clay is not suitable because it is inclined to retain water, become sour and spread disease. Unless the soil where the poultry house is to be located is rather sandy, it should be underdrained in order to keep water from coming up through the floor and also to avoid mud from being tracked into the house, a condition developing filth and conducive to the outbreak of disease.

Exposure.—A southern or southeastern exposure is always desirable, unless the prevailing winds make another exposure more desirable.

Convenience.—A factor of great importance in determining the location of the laying house has to do with the personal idiosyncrasies of the attendant. On many farms the farmer's wife is the "poultryman" and she frequently decides that the laying house must be located in a convenient place for her to attend to the chickens. The result is that in many cases the laying house is located near the living house. The convenience of the house on the part of the attendant is regarded as more important than the comfort of the birds. Oftentimes the financial returns from the flock are sacrificed in order to have things convenient.

Adequate Sanitation.—As a matter of fact, the laying stock should receive first consideration if the best returns are to be expected. The laying house should be located so that adequate yarding arrangements may be provided. The principles involved in providing yarding arrangements for laying stock are discussed on pages 565 and 566, suffice it to say at the present time that unless the house is located so as to avoid in so far as possible infection of internal parasites and other troubles, there is bound to be loss from disease and other causes. Tuberculosis is often the cause of poor results in the laying stock. It is for this reason that the laying stock must be kept separate from other classes of live stock, especially swine, because it has been established that swine may become infected with the avian type of tuberculosis. Rather than giving the laying stock the freedom of the farm, especially the hog lots and cow and horse stables, it is much wiser to provide housing and yarding arrangements so that the laying hens are always kept by themselves. The laying house, therefore, should be located with this object in mind. In order that the greatest profits may be secured in egg production, it is highly important that the laying stock be provided with houses and other environmental conditions that will give them the greatest comfort and keep them in the best of health at all times, and this can be accomplished only when they are kept separate from other classes of live stock.

The Style and Capacity of Laying Houses.—The more important principles to be kept in mind in determining the style and capacity of laying houses have been discussed by Jull and Lee (1928*b*) as given in subsequent remarks, to which the observations of others have been added. The size of the flock determines the dimensions of the laying house. For instance, a back-yard flock is usually limited in numbers, and, since the floor space required is not very great, the house is normally not more than 12 ft. deep, whereas with a large commercial flock the house should probably be about 20 ft. deep. On the other hand, in some sections of the country, land is cheap enough and climatic and other conditions favorable so that large flocks are housed in colony houses, each colony

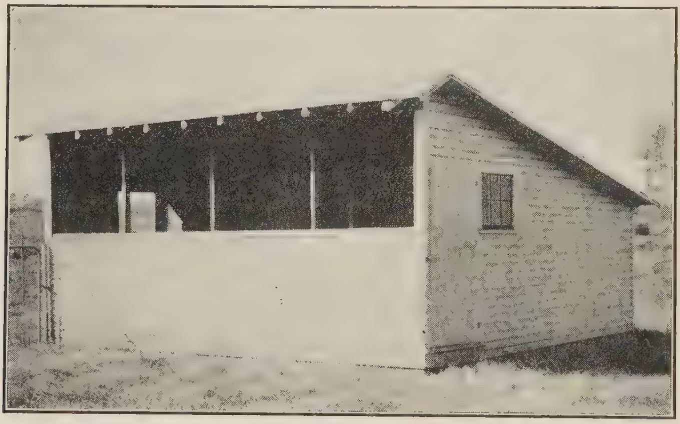

Fig. 105.—A 20 by 20 ft. shed-roof laying house as used in South Carolina. Climatic conditions in the South permit the use of an open front the year round. (*Photograph by the S. C. Coll. Agr.*)

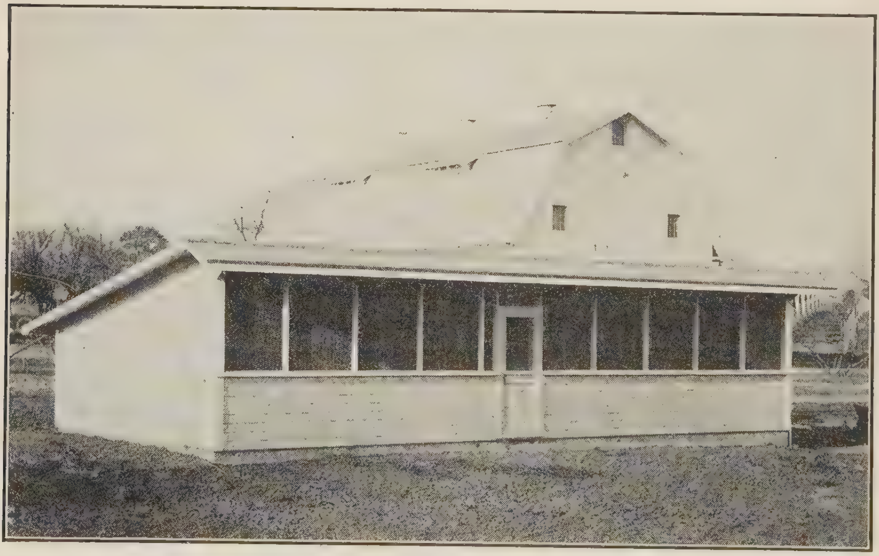

Fig. 106.—A 20 by 40 ft. shed-roof, multiple-unit house on the poultry plant of the Georgia College of Agriculture. (*Photograph by Ga. State Coll. Agr.*)

house accommodating from 25 to about 100 birds. In the case of most farm and commercial flocks, however, stationary houses are preferable because of the lower cost of construction, and less labor is required in caring for the birds. In many such cases colony houses are provided for the breeders, while the layers are kept in the stationary houses. The advantages of this system are that the layers may be fed and managed so as to get the maximum fall and winter egg production, while the breeders are given a rest in the fall and then are provided with whatever range is possible before and during the breeding season, in order that hatching eggs of the highest quality may be obtained.

A house so built that the attendant can stand up and work conveniently will have cubic air space enough if from 3 to 5 sq. ft. of floor space per fowl is allowed. The extent of floor space necessary depends on the housing system employed, size of flocks, weather conditions and size of the birds. Where the climate is mild and the hens have free range most of the year, more birds can be kept on a small floor area under the colony system than under the intensive system.

Floor Space.—In 1911 Halpin and Ocock recommended 5 sq. ft. floor space per bird for flocks of 50 hens and 4 sq. ft. per bird for flocks of 100 birds. Davis and Lippincott (1912) stated that "If we build poultry houses on the basis of allowing a cubic foot of air space per pound live weight as we do barns, a 5-lb. hen with 5 sq. ft. of floor space allotted to her would have a house but one foot high." Richardson (1915) recommended a little over 3 sq. ft. for laying hens in New Hampshire. Commercial poultrymen in New Jersey were found by App, Waller and Lewis (1918) to give 3.9 sq. ft. floor space to the layers. Philips (1923) recommended 4 sq. ft. floor space for layers in Indiana. Carver, Shoup, Buchanan and Smith (1925) made the following observations and presented a table showing the number of birds to be housed in houses of various styles.

> The size of the building will be determined by the need, the number of hens to be housed and whether they are to be confined to the building or allowed free access to range. The smaller the house unit, the more square feet required per hen; the larger the unit the fewer square feet required per hen. The following table gives the capacity of the buildings described.

Style of building	Square feet	Leghorns	Heavy breeds
20 × 20	400	100	90
30 × 30	900	300	275
24 × 24	576	190	175
20 × 30	600	200	180
20 × 75	1,500	500	450
20 × 130	2,600	1,000	800

It is not advisable to house more than 500 Leghorns or more than 200 of the heavier breeds in the same unit, though they may be under the same roof. The building should be filled to capacity in winter, and should never be crowded in summer.

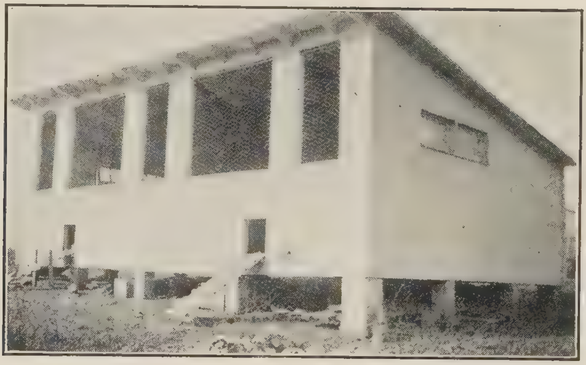

FIG. 107.—A shed-roof, open-front type of house recommended for Arkansas. (*Photograph by Ark. State Coll. Agr.*)

Laying Flock Units.—Colony houses accommodating from 30 to 50 hens are about as large as can be moved easily, but larger numbers may be kept in one flock in a long house. Flocks of from 100 to 500 are well adapted to average conditions for the production of market eggs. Large flocks require less labor, fewer fences, and a lower house cost per bird than small flocks, but there is a greater risk of disease and the individual hen receives less attention. It is for this reason as well as the fact that the smaller the laying unit usually the better the egg production per bird that units of 250 layers are regarded as the maximum number that should be kept together.

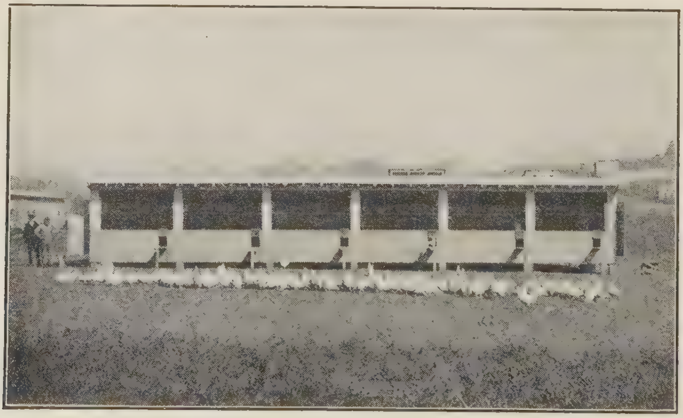

FIG. 108.—An open-front, shed-roof type of laying house recommended for Tennessee. The house is 20 ft. deep and 60 ft. long and accommodates 300 laying hens. (*Photograph by Tenn. State Coll. Agr.*)

Large Laying Houses.—With the development of modern feeding practice, which makes it possible to keep laying hens confined the year round, an increasing number of poultrymen use two- to four- and five-story buildings for the layers. Barns, dairy stables and even silos have been converted into laying houses. The use of such large houses reduces the labor required to manage large flocks as compared with keeping them in single-story houses. Where proper environmental conditions are provided for the laying stock, two- to five-story houses give satisfactory results.

A Combination Brooding and Laying House.—On many farm and commercial poultry plants the poultryman is confronted with the problem of providing sufficient house room for both the new crop of pullets that should be put in the laying houses by about September and the hens that already occupy the houses. A very practical way of overcoming the difficulty is recommended by Jones (1929). He advises building what he calls a "barracks" house, which can be used for brooding the chicks in the spring of the year, finishing the cockerels as broilers after the pullets have been taken to the range and keeping the hens from the time the pullets require the laying house until the hens have completed their summer and fall egg production.

The need for and advantages of using the barracks-house system are discussed by Jones in the following terms:

> Old hens in heavy production through the late summer and fall, as compared to pullets, are particularly profitable because they lay large eggs at a time when the market is short and high premiums are paid. To neglect the pullets, leaving them on range after they start to lay, means that they will lay small eggs, lose flesh and will be less profitable than if housed at the time production starts. Some poultrymen are meeting this problem by building a new laying house each fall, and this works well so long as a program of steadily increasing plant capacity can be maintained.
>
> Another problem confronting poultrymen at the present time is the labor involved in brooding early chicks in colony houses. Many would like and would be willing to build a large brooder house if the house could be kept profitably employed during the entire year. Still another perplexing poultry problem is, where to house and finish broilers when the pullets need all of the available range and brooder house capacity. The barracks-house system of management answers all these needs in a way that is economical and practical.
>
> The barracks house may be a long hen house with a hen capacity of 30 to 40 per cent of the laying houses on the plant. It should be located as near the center of activities as possible, easily accessible for the delivery of feed and coal, and be equipped with running water. While such a house should be located near other buildings for convenience, it should at the same time be far enough away from laying houses to prevent tracking disease from the old stock to the young stock.
>
> The barracks house should be constructed so that it can be used either as a brooder house or as a laying house. It may be equipped with individual brooder

stoves placed in each pen during the brooding period, or it may be heated with the pipe system running through the back of the house. Such a house should be not less than 20 ft. deep, and not over 30 ft. deep; 20 × 30 and 24 × 24-ft. pens are proving most popular. When stove brooding is practiced, each pen should be equipped with a brooder stove and a low temporary partition. When equipped with hot-water pipes at the rear, the covering over the pipes may serve as drop boards during the period when the house is used for laying hens.

A litter carrier running the entire length of the house will do much to cut down labor, particularly when cleaning during bad weather. A wire platform 6 to 12 ft. wide in front of the house will serve better than a yard for brooding and can be kept clean. Half-inch square-meshed wire is most satisfactory for young stock and can be used for older stock.

The barracks system meets a long-felt need which makes it possible to house both hens and early hatched pullets in laying quarters where they can give satisfactory returns and allow keeping a maximum number of laying hens during the season of highest egg prices. The barracks system also provides a large brooder house for starting chicks early in the season, and for finishing cockerels later in the season without the economic loss of having that house idle during the remainder of the year.

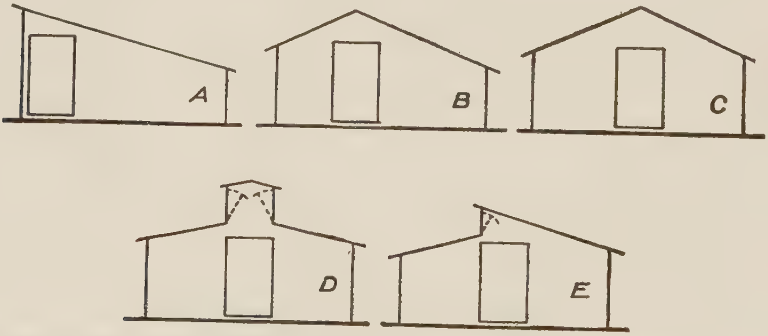

FIG. 109.—Types of roofs of poultry houses. *A*, shed roof; *B*, combination; *C*, gable; *D*, monitor; *E*, semimonitor. (*U. S. Dept. Agr.*)

Details of Constructing Laying Houses.—The manner in which the laying house is constructed has a great deal to do with the results secured from the laying stock. The details of building laying houses have been covered by Jull and Lee (1928*b*) of which the following is a condensed abstract:

The roof should be well constructed and made water tight. Shingle roofs should have a one-third pitch, while composition or metal roofs may have a smaller pitch or be almost flat. However, the roofs with considerable pitch will last longer than roofs which are nearly flat. Different types of roofs are illustrated in Fig. 109.

The Shed Roof.—The shed or single-slope roof is practical for houses up to 20 ft. or more in width if a girder and posts support it. A girder is needed only in shed-roof houses wider than 14 ft., except in sections where there is considerable snow, in which case the space should be reduced to 12 ft.; 20 ft. is as wide as is usually used for a house for laying hens, although even wider houses are used successfully. The shed-roof type is practical and easy to build and allows a high front to the house.

The Combination Roof.—The combination or two-pitch roof (Fig. 109*B*) and the semimonitor roof (Fig. 109*E*) are adapted for buildings from 16 to 24 feet wide, while either of these styles or the monitor (Fig. 109*D*) and the gable (Fig. 109*C*) roofs may be used for wider buildings. The combination roof on a house more than 16 ft. wide gives good headroom at a moderate cost, reduces the surplus air space, and makes a good-looking building. Great care must be taken in the case of the monitor and semimonitor types of houses to avoid drafts. They are not recommended for general use.

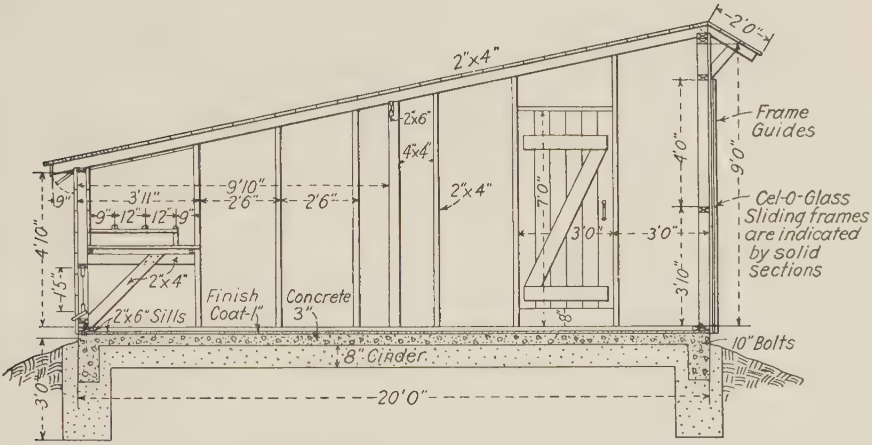

FIG. 110.—Cross-section view of New Jersey multiple-unit laying house, showing shed-roof type and concrete floor detail. (*Sketch by Acetol Products, Inc.*)

The Gable Roof.—The gable roof is used extensively for two-story buildings. This style of roof is usually ceiled at or slightly above the eaves, or the loft may be filled with straw or some other absorbent material, which tends to keep the house dry and warm. If straw is used, there should be an opening in each gable to allow air circulation.

The Front.—A house with the entire front open is commonly used in the South. One in which from one-fourth to one-third of the front is curtains and windows is used in the northern part of the United States. Curtains and windows make up from one-third to one-half of the front of the house in the sections between these two extremes. The openings in the front are covered by glass and muslin curtains or with glass substitutes, so that the amount of open space can be varied according to the season and weather conditions.

The front of the house should be high enough so that the windows or openings will allow the sun to shine well back into the house in winter. The depth which the sun's rays shine on the floor of the house in the vicinity of Washington, D. C. (latitude 40° N.) on Jan. 1 is given in the accompanying table.

Height of Top of Windows Feet	Inches	Depth of Sunshine Feet
3	6	8
4	5	10
5	4	12
6	2	14
7	1	16
7	11	18

Sunlight Important.—The arrangement of the windows and openings over which duck cloth, burlap or glass substitute is used is a very important matter, because they should not only provide for ventilation and proper lighting of the house but also be so arranged that the greatest amount of direct sunlight or ultra-violet rays have access to the inside of the house when the windows can be opened and the duck cloth, burlap curtains or glass substitute raised. Direct sunlight is very beneficial in keeping the hens in good health and in promoting the efficient use of minerals which the birds consume. The ultra-violet rays of the sunlight do not penetrate glass to any extent and duck cloth or burlap only to a limited extent, so that, whenever possible, without causing drafts, the front of the house should be opened and the windows and curtain openings should be where the maximum amount of direct sunlight may reach the floor of the house. A number of glass substitutes are on the market and for a discussion of their value to birds kept in confinement see pages 359 to 361.

Concrete Floors Best.—Concrete floors usually are the best because they are easy to clean, sanitary and rat proof, and are comparatively inexpensive where gravel and sand are cheap. Keep concrete floors well bedded with straw or some kind of litter, especially in winter, so that they will be dry and not too cold. Board floors too close to the ground make rat harbors and soon rot out.

Partitions in Long Houses.—Partitions in long laying houses are necessary to break possible drafts; the lower 3 ft. of the partitions may be solid and the upper portion wire netting, or solid partitions may be used. Partitions extend across the house every 25 to 40 ft., depending on the length of the house.

Interior Fixtures.—The interior fixtures of the pens should be simple, inexpensive, and easy to clean. Roosts and droppings boards may be made removable, but satisfactory results are also secured if they are made permanent, with as few cracks and hiding places for mites as possible. The use of carbolineum (anthracene oil) or black leaf 40 (see p. 431) on the roosts and roost supports makes it unnecessary to make the fixtures removable except in the South.

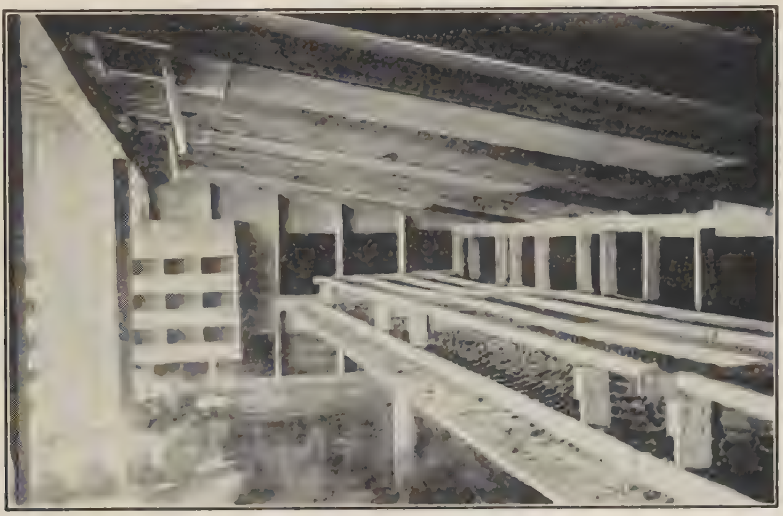

FIG. 111.—Interior view of Michigan shed-roof type laying house. Note the ventilator at the left and the wire netting under the roosts. (*Photograph by Mich. Agr. Ext. Service.*)

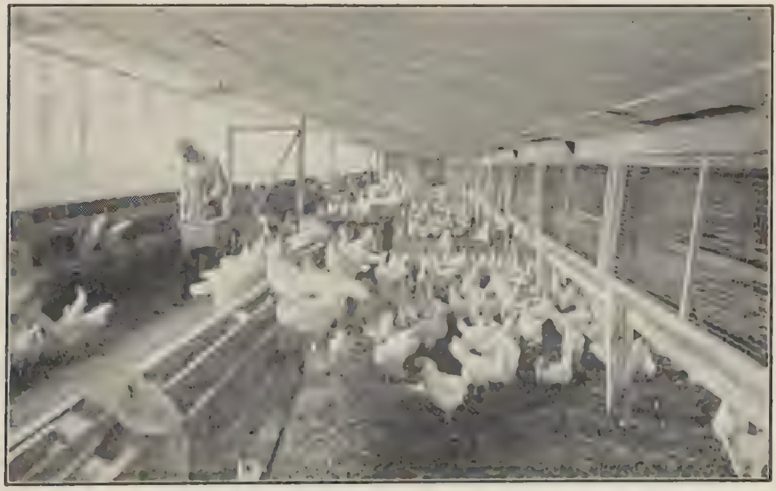

FIG. 112.—Interior view of laying house of John Elleman, Indiana, showing screen frames lowered to keep the birds off the droppings boards. (*Photograph by American Poultry Journal.*)

Roosts.—Roosts are usually placed next to the end or back walls, 6 to 8 in. above the droppings boards, while the latter are made from 20 in.

to about 3 ft. above the floor. All roosts should be on the same level; otherwise the birds will crowd and fight to get on the highest. Scantlings 2 by 3 in. or 2 by 4 in. with the narrow surface up and upper edges rounded off make good roosts. By hinging the roosts to the back of the house the droppings boards may be readily cleaned, and this arrangement also makes it easy to properly disinfect both roosts and droppings boards. For Leghorns 7 in. of roost space per fowl should be allowed and 10 in. for Plymouth Rocks or birds of that size, while larger fowls require still more space. As many roosts should be used as are necessary to accommodate the fowls comfortably, two roosts generally being used in narrow houses and three, four and sometimes five in wide houses. Roosts should be placed about 13 to 15 in. apart for Leghorns and 15 to 18 in. apart for Plymouth Rocks, but the outside ones may be within 12 in. of the edge of the droppings boards.

It is a good practice to place wire netting 1½ in. mesh No. 16 gage, immediately beneath the roosts to prevent the hens from picking at the droppings (see Fig. 111). This prevents the hens from consuming many worm eggs frequently contained in the droppings.

Materials Used in the Construction of Laying Houses.—Wood in various forms is the cheapest and most commonly used material for building laying houses. Jull and Lee (1928*b*) offer the following observations: The framework consists of the sills, which support the building; the studs or uprights, which rest on the sills; the plate, which is on top of the studs; and the roof rafters, which rest on the plates. The sills are placed on wooden posts, stones, or concrete supports, or directly on top of concrete walls. Wooden posts should be from 6 to 8 in. in diameter, placed 6 to 8 ft. apart, and 2 to 3 ft. in the ground or below the frost level. Cedar, locust, chestnut, redwood and cypress are preferable to most other woods. Concrete posts may be used in place of wooden posts and are much more durable.

Sills.—The sills may be either 2 by 4 in. or 4 by 4 in., depending on the size and construction of the building. Sills 2 by 4 in. are heavy enough for colony houses or those of light, single-wall construction if sufficiently supported, while sills 4 by 4 in. are used for larger buildings and for houses with double walls. Sills 4 by 6 in. are used in 2-story henhouses or other large poultry buildings, and should be set on edge, unless on a concrete or stone wall, when a lighter sill may be used and laid flatwise. Concrete walls are commonly used as foundations for large poultry houses, with a 2 by 4-in. sill, which is bolted to the walls. The posts or supports must be set close together if light sills are used.

Runners.—Runners 3 by 4 in. or 4 by 6 in. are used as sills for portable houses, which require heavy framework. Portable houses which are to be moved on runners must be braced extra well in the corners to stand the strain of moving.

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Joists.—Floor joists may be of 2 by 4 or 2 by 6-in. lumber, depending on the span. They should be from 16 to 20 in. apart. If the span is over 10 ft. a center support shoud be used for 2 by 4 joists.

Squaring the House.—To square the corners of a poultry house, fix one line or side of the proposed house. With this as a base, locate the other corner posts by using the 6, 8 and 10-ft. combination, measuring 6 ft. from one end of the fixed line and 8 ft. from the same end at right angles. The angle between the two lines is fixed by a rule 10 ft. long running from the 6-ft. mark of the fixed line to the end of the 8-ft. line, thereby

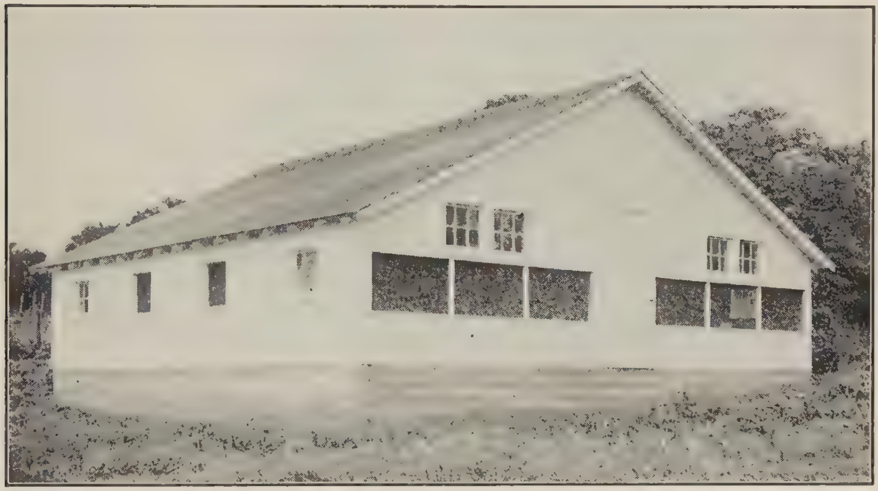

FIG. 113.—The Missouri straw-loft laying house, 30 by 30 ft. The gable is filled with straw to absorb the dampness, thus tending to keep the house dry in winter and cool in summer. (*Photograph by Mo. State Coll. Agr.*)

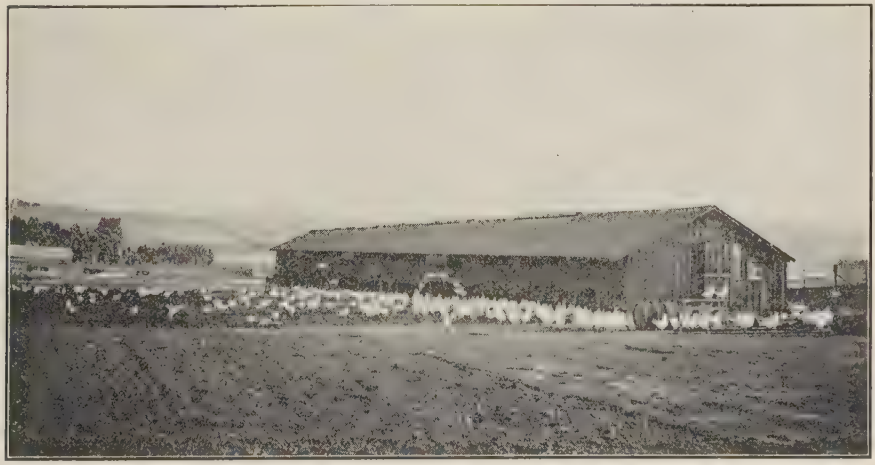

FIG. 114.—A type of laying house common in California, where sunshine is abundant and land is relatively cheap. (*Photograph by Petaluma Chamber of Commerce.*)

making a square corner. A triangle whose sides are 6, 8 and 10 ft. long, respectively, contains a right angle opposite the diagonal side.

The sill in small buildings may be made level by driving a stick at one corner of the house, to which a straightedge or a long, straight stick is nailed at the desired height of the posts or sill. A spirit level is used on this straightedge to make the posts at the right height or to make the sill level. A transit is generally used in laying out large buildings.

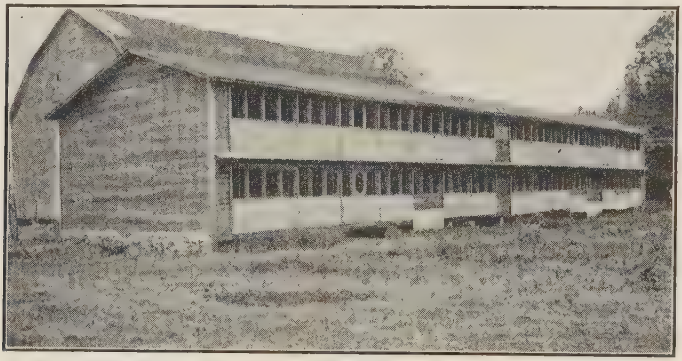

Fig. 115.—A double-deck laying house on the farm of S. Hood, Massachussetts. (*Photograph by Mass. Coll. Agr.*)

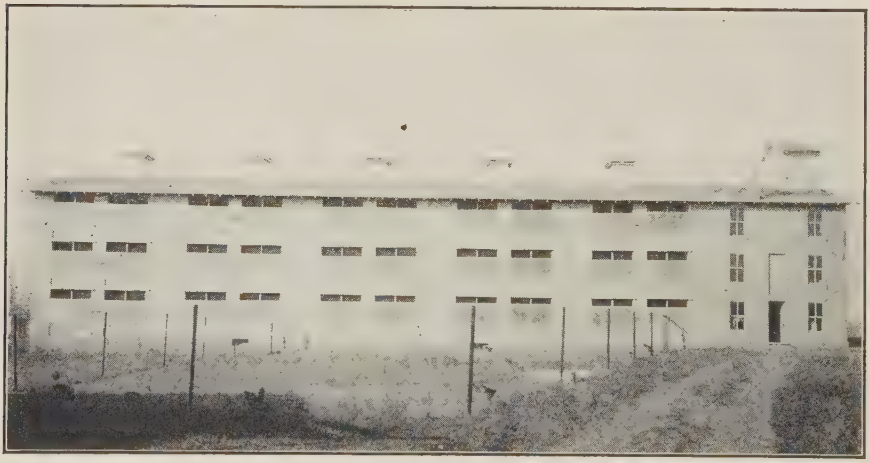

Fig. 116.—A three-story laying house in Pennsylvania, equipped with cel-o-glass windows. (*Photograph by Acetol Products, Inc.*)

Studding.—The studding is toenailed on the sill and should be set plumb with a spirit level and braced well until sheathed. The studding is set from 2 to 4 ft. apart for the rear walls and is placed to fit the windows, curtains and doors in the front and ends. The studs should be placed so that the lumber will cut with little waste. Less studding is required if the building is boarded up and down rather than horizontally, as in the former case only a few studs with cross-studding or ties are required. Studs 2 by 4 in. are commonly used, except that in large houses the corner studs are generally doubled, making them 4 by 4 in.

Plates.—Plates are halved or spliced and nailed together at the joints or ends, which should be made over a post or stud. The plates are spiked at the top of the studding and are made of 2 by 4-in. scantling, laid flat on top of the studs, or 4 by 4 made by spiking two 2 by 4's together.

Rafters.—Rafters may be 2 by 4 in. or 2 by 6, the 2 by 4's being used only in light buildings where the clear span is not more than 12 ft. and 2 by 6's for longer spans and in climates where roofs have to bear much snow.

Purlins.—It is advisable to use purlins in buildings where rafters are more than 12 ft. long. Purlins are usually made of 2 by 4 or 2 by 6-in. material set on edge on posts to support the roof. They are placed lengthwise of the house about midway the length of the rafters, which rest on them. In a deep house which has a wide droppings board the purlin may be placed at the front edge of the droppings board, so that the posts supporting the purlin will not be in the way in the pens.

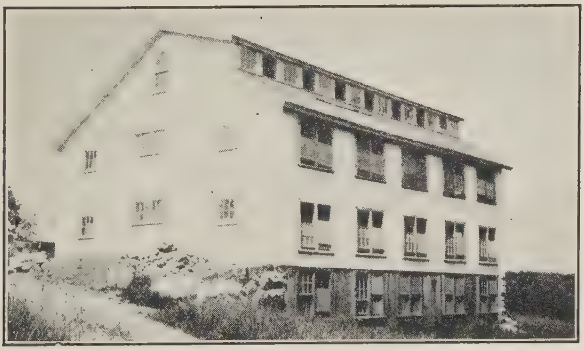

Fig. 117.—A four-story laying house on the farm of J. Warren, Massachussetts. (*Photograph by Mass. Coll. Agr.*)

Roofs.—In roofs that form a ridge a board may be placed between the ends of the rafters to keep the ridge straight and even, but this is not necessary in most poultry houses. Collar beams or cross-ties 1 to 6 in. are used to prevent the spreading of the rafters on gable or combination roofs. They should be placed as low as possible on the rafters, so as to stiffen the frame, but not so low as to interfere with head space. If the hens roost on them, cover the space between them and the rafters with wire netting.

In erecting the rafters one pair may be set in position and the rest marked from these. They should be notched only deep enough to make a snug fit and to provide good nailing on the plates, because deep notching weakens them. Rafters are usually spaced 2 ft. apart, from center to center, so that the roof boards will cut with minimum waste.

Laying the Floor.—The best concrete floors are made by first putting down a firmly tamped foundation of cinders, broken stone or gravel not less than 6 in. thick and then laying on it from 3 to 4 in. of concrete. A layer of tarred building paper, lapped and cemented with tar at the seams, may be laid between the stone foundation and the concrete to prevent moisture from coming through the earth and concrete and making the floors damp. Care should be taken not to break holes in the paper.

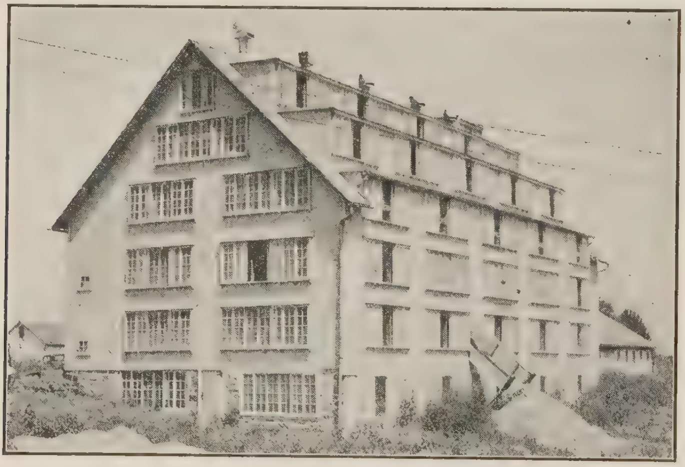

Fig. 118.—A laying house, accomodating 6,000 layers, on the farm of Mr. Moore, Ohio. (*Photograph by Ohio State Coll. Agr.*)

Wooden floors, in most parts of this country, are usually made of one thickness of matched flooring. In the extreme northern sections they are generally doubled to make them tight and warm, in which case the lower layer of boards is usually laid diagonally and building paper is placed between the floors.

Roofing Material.—Prepared roofing, laid on wide matched sheathing, is ordinarily used for covering the roof. Wooden shingles are used in only a few sections of the country, principally on the Pacific Coast. One- or two-ply roofing material is usually used on the sides, and one-, two-, or three-ply roofing on the roof, the choice varying with different styles and grades of manufacture. This prepared roofing material may be had in the form of shingles or in rolls. Directions and materials for laying are supplied with the roofing. The sheathing should be planed on one side and laid close together, with the surface side up to present a smooth surface for the prepared roofing. Sheathing paper is sometimes used between the sheathing and the roofing material. Prepared roofing may be used on roofs which have a slope of 1 in. or more to the foot.

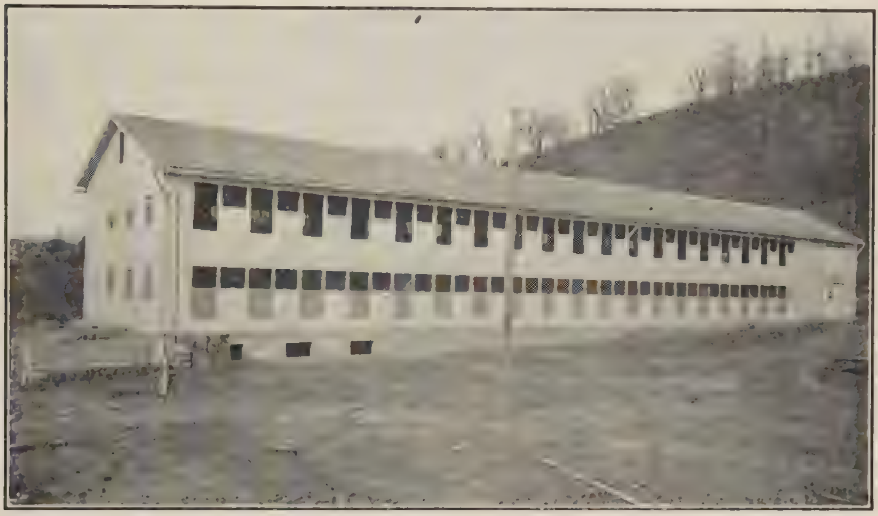

Fig. 119.—A long, two-story house equipped with cel-o-glass windows. (*Photograph by Acetol Products, Inc.*)

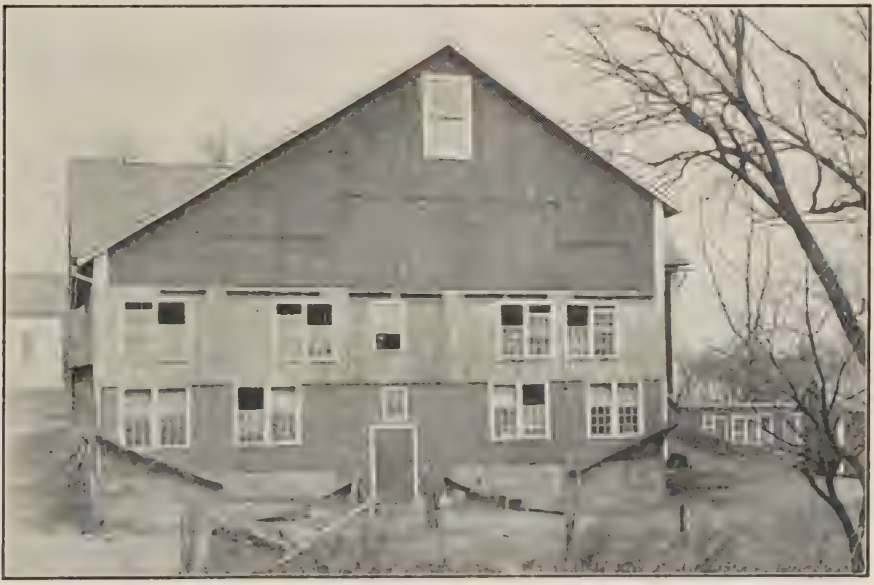

Fig. 120.—A barn converted into a laying house in Ohio. (*Photograph by Ohio State Agr. Exp. Sta.*)

Such roofing will last longer on a roof which has considerable slope than on a roof which has only a slight slope. A shed roof is the easiest one to cover with prepared roofing, which lasts especially well on this type of roof, because it has a northern exposure and is not so much affected by the sun. The best way to fasten the loose ends of roofing paper is to bend them under the sheathing, fastening the paper with a narrow board.

Wooden shingles may be laid from 4 to 5 in. to the weather on roofs which have at least a one-third pitch, which is a rise of 8 in. to the foot, or a total height equal to one-third of the span of a gable roof or two-thirds of the span of a shed roof. Cedar and cypress shingles are usually laid not more than 5 in. to the weather on walls, and are not generally used on roofs which have a rise of less than 8 in. to the foot. Wooden shingles should be laid on narrow sheathing 3 to 5 in. wide, or on common sheathing, and should break joints at least 1 in. and as much more as possible. The sheathing boards should be spaced about 3 in. apart to allow the roof to dry out quickly. Four bundles of wooden shingles are the equivalent of 1,000 shingles 4 in. wide, and estimates are made on this basis; 1,000 shingles laid 4 in. to the weather will cover about 125 sq. ft. depending on their size.

Plans and specifications of poultry houses suitable for different states may be secured from the poultry department of the state college of agriculture or state experiment station, a list of which is given on page 572.

CHAPTER XX

HOUSING EQUIPMENT AND APPLIANCES

Properly equipping the houses and the providing of certain appliances are necessary for the efficient management of the growing and adult stock. Oftentimes the installation of suitable equipment and the use of simple appliances saves much labor and proves to be one of the best investments in management practice. Moreover, with proper equipment in the brooding and laying houses, the birds are given a better chance to grow properly and lay well than where there is inadequate equipment. Then again, the use of a few applicances aids in keeping the houses clean.

Grain Bins.—In order to save labor in transporting scratch grain and mash to the laying houses, it is often desirable to have a grain bin either in or adjoining the laying house. The bin should be located at least 10 or 12 in. above the floor level and should be lined with tin to prevent the depredations of mice and rats.

Mash Hoppers.—The dry-mash portion of the ration for growing chicks and laying hens should be fed in self-feeding hoppers. Self-feeders enable the birds to eat at all times during the day. The hoppers should be large enough to hold a quantity of mash and should be so constructed as to avoid any waste. Mash hoppers for growing stock

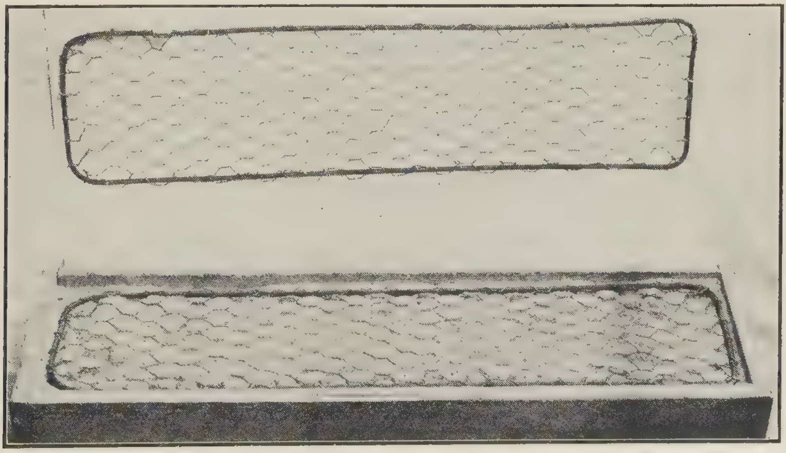

Fig. 121.—Open trough for feeding mash to chicks. The grid, shown above and in place, permits chicks to have easy access to the mash but prevents waste from scratching. (*Photograph by Ohio State Agr. Exp. Sta.*)

used on the range must be so constructed as to prevent rain from getting into the mash, while mash hoppers used in houses do not require a covering but should have a reel or device for preventing the birds from getting into the mash or roosting on the hopper. Types of suitable hoppers for outside and inside use, respectively, are shown in Figs. 121, 122, 123 and 124.

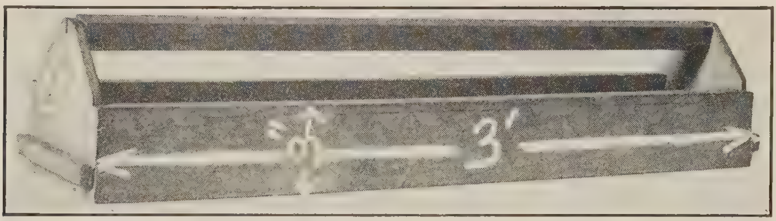

Fig. 122.—An open mash hopper with a reel to prevent the chicks from getting into the hopper and soiling the mash. Suitable for chicks after about 3 weeks old. (*Photograph by Ill. State Coll. Agr.*)

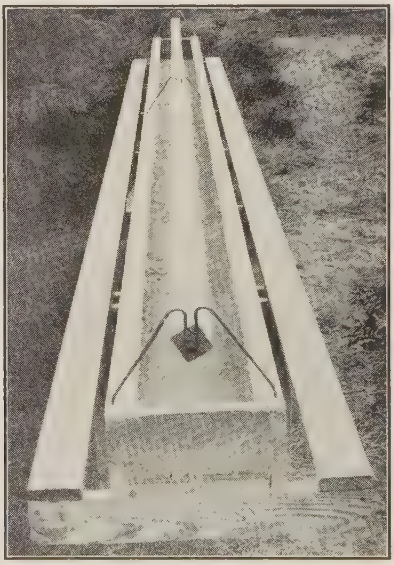

Fig. 123.—A reel self-feeding mash hopper for layers. (*Photograph by Ohio State Agr. Exp. Sta.*)

Wet-mash Troughs.—When wet mash is fed, a V-shaped trough is most suitable.

Feed Carriers.—Labor-saving conveniences in the way of feed carriers constitute a good investment on commercial poultry plants. A horse and wagon saves many steps in carrying grain to the various houses. A feed carrier suspended from an overhead track is shown in Fig 125.

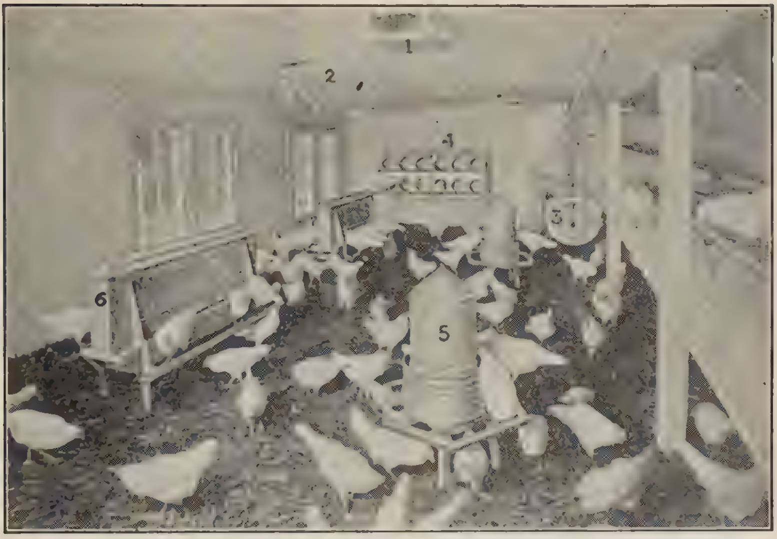

FIG. 124.—The interior view of a well equipped laying house. 1 and 2 are part of the ventilating system. 3 is the litter carrier running in front of the droppings board. 4 shows the nests. 5 is the watering fountain. 6 is the self-feeding mash hopper. (*Photograph by Poultry Item Publishing Co.*)

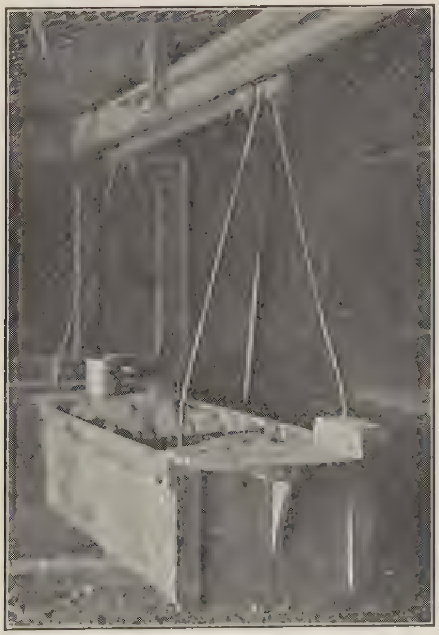

FIG. 125.—An overhead carrier for transporting feed from the feed house to the laying houses. (*Photograph by U. S. Dept. Agr.*)

Grit and Oyster-shell Hoppers.—Grit and oyster shell are fed in what are known as "open self-feeding hoppers." The essential feature connection in with the feeding of grit and oyster shell is that they be always accessible in a clean condition.

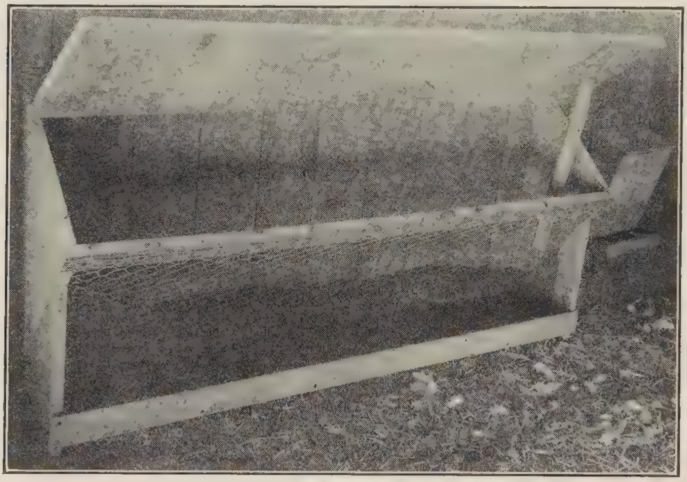

Fig. 126.—A satisfactory type of self-feeding hopper for green alfalfa and other forms of green feed. (*Photograph by Calif. State Coll. Agr.*)

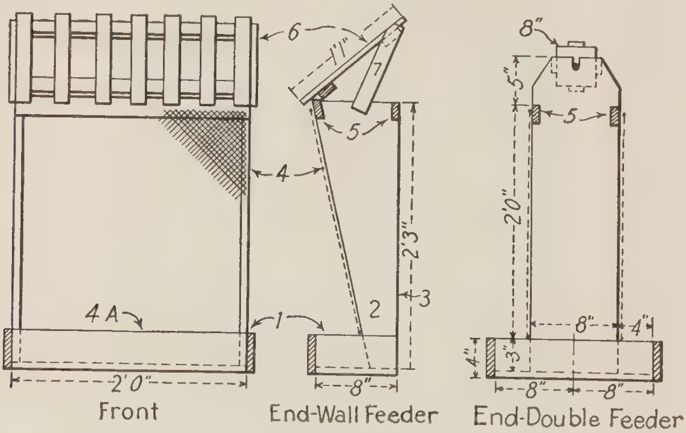

Fig. 127.—A satisfactory type of self-feeder for green feed. (*Ohio Agr. Exp. Sta.*)

Fresh Green-feed Hopper.—In some sections of the country fresh alfalfa is supplied as a source of green feed and suitable hoppers in which it may be fed are illustrated in Figs. 126 and 127.

Watering Devices.—Clean water should always be available for all classes of chickens. When pans and pails are used they should be so arranged that the birds can not get into them to contaminate the water with their dirty feet. If pans for growing chicks are used, they should have a wire or slat covering so arranged as to keep the chicks out of the pan itself. For the laying stock, pails on a stand is a very convenient method of insuring an abundant supply of clean water (see Fig. 128).

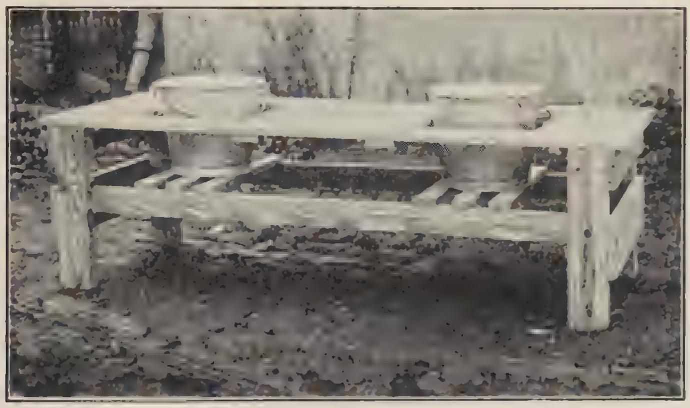

Fig. 128.—A slatted platform for the water pails for laying stock. (*Photograph by Ili. State Coll. Agr.*)

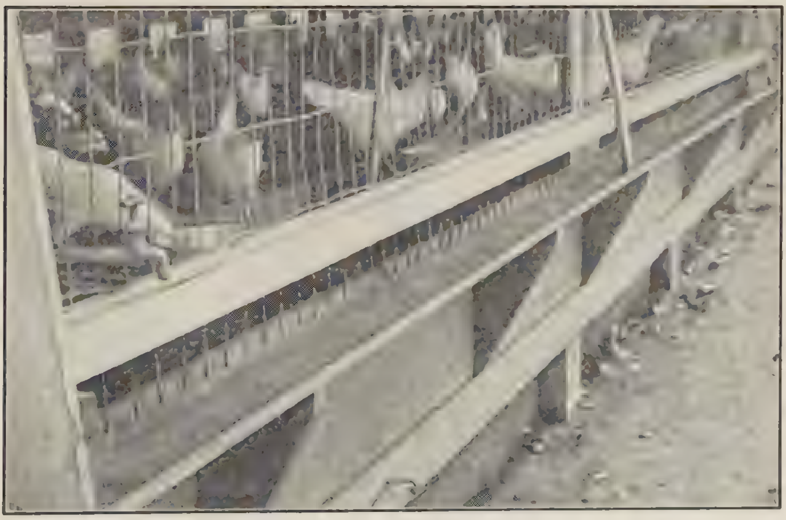

Fig. 129.—A continuous supply of fresh water is insured in this arrangement in a Washington State laying house. Milk pans are located on the inside and the mash hopper is located beneath the water trough. (*Photograph by Wash. State Agr. Exp. Sta.*)

In southern and other parts of the country where there is little danger of the water freezing during the winter months, watering pipes are frequently conducted into the houses or to the fronts of the houses so that running water is available at all times. Usually a long watering trough is located on a platform some distance above the floor, and a float is

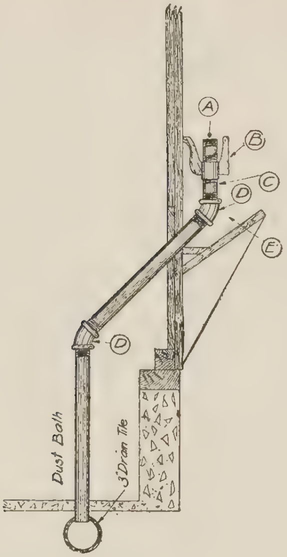

FIG. 130.—Cross-section showing overflow of the running water system shown in Fig. 129. To prevent clogging, all overflow pipes are 2-in. in diameter and right-angle connections are used.

A. Loose nipple 1½ in. long which holds the water to the desired level in the trough. It is easily removed with the fingers to flush the trough.

B. Cross-section of 3 by 4-in. wooden guttering with the O. G. side toward the wire front to make the feed trough more accessible.

C. 1-in. coupling which is fitted tightly into bottom of water trough and permits easy removal of nipple *A* for flushing.

(NOTE.—Arrow in illustration points by mistake to nipple below coupling instead of to coupling itself.)

D. 45-deg. elbows.

E. Lower feeding trough used for feeding wet mash and lawn grass. (*Wash. Agr. Exp. Sta.*)

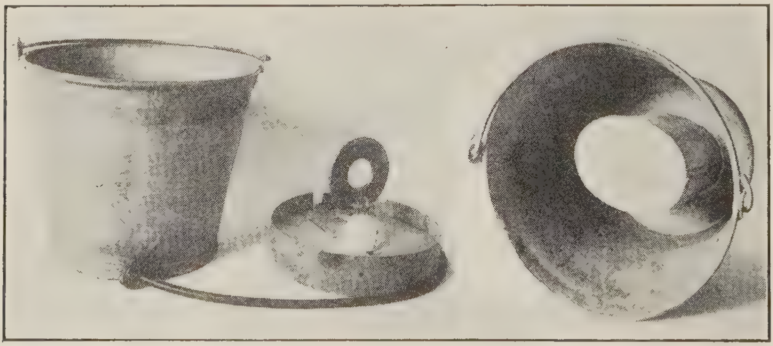

FIG. 131.—An electrical apparatus for keeping the water accessible for the layers at all times. The illustration on the left shows the base with its electrical unit and the pail into the bottom of which it fits. The illustration on the right shows the water pail with the indentation for the electrical unit. (*Photograph by Ill. State Coll. Agr.*)

attached to the top so that an overflow is avoided. Such a watering device is illustrated in Figs. 129 and 130.

In the northern parts of the country the water usually freezes in the laying houses unless it is heated in some way. Water fountains and

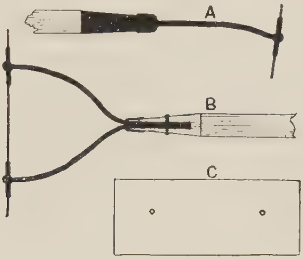

FIG. 132.—Scraper for cleaning droppings boards.

A. Side view of scraper. Note how the lower edge is turned in ½ in. to make it cling to the boards. For scraping next to wall, turn scraper over and use top edge.

B. Top view of scraper showing attachment to rake or hoe handle. The handle is 4 to 5 ft. long and should be strong, rather stiff, but not too heavy. The handle should have a strong iron ferrule to receive forked irons connecting handle to scraper. These irons may be made of 5/16 or ⅜ square or round steel to make it strong and stiff. The ends which go into handle may be tapered or reduced in size somewhat and welded. Make sure it is riveted through the ferrule.

C. Blade for scraper 4 by 10 in. The 3/16 or ¼-in. holes are 2 in. from ends and the edge of holes is ¼ in. above the middle. (*Ohio Agr. Exp. Sta.*)

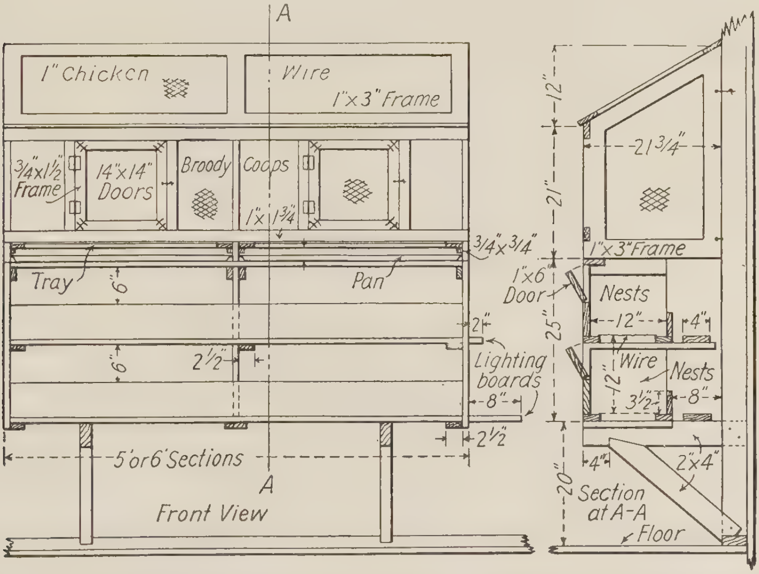
A
1" Chicken
Wire
1"x3" Frame
¾"x1½" Frame
14"x14" Doors
Broody
Coops
1"x1¾"
¾"x¾"
Tray
6"
Pan
2"
Lighting boards
8"
6"
2½"
2½"
5' or 6' Sections
A
Front View
12"
21¾"
21"
1"x3" Frame
1"x6" Door
Nests
12"
4"
25"
Wire
12"
Nests
3½"
8"
4"
2"x4"
20"
Section at A-A
Floor

FIG. 133.—Dark nests and broody coop above them. (*Sketch by Wash. State Agr. Exp. Sta.*)

pails have been designed that are heated with lamps, electric bulbs and especially constructed heating elements. The use of lamps for heating the water container is not advised because of the relative danger from fire, particularly where the electric current is available. A watering device heated electrically is shown in Fig. 131.

Oat Sprouter.—When sprouted oats are fed as a source of succulent green feed, it is necessary to have an efficient means of sprouting them. A heated room is necessary, and if a small quantity of oats is to be germinated or sprouted, buckets may be used, or the more simple method of sprouting oats on a table may be used. Where relatively large quantities are required, as on commercial poultry plants, then the sprouting should be done in a specially heated room equipped with trays.

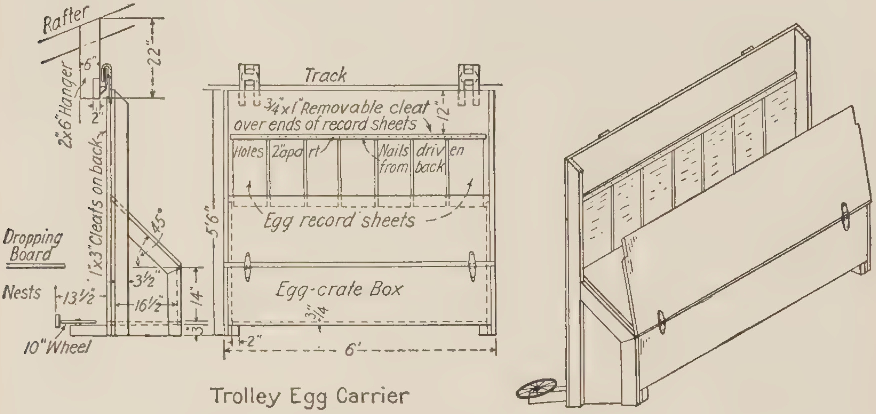
Rafter
6"
22"
2"x6" Hanger
2"
1"x3" Cleats on back
45°
Dropping Board
3½"
Nests
13½
16½"
14"
3"
10" Wheel
Track
¾"x1" Removable cleat over ends of record sheets
12"
Holes 2" apart
Nails driven from back
Egg record sheets
5'6"
Egg-crate Box
¾"
2"
6'
Trolley Egg Carrier

Fig. 134.—Trolley egg carrier. (*Plan by Wash. State Agr. Exp. Sta.*)

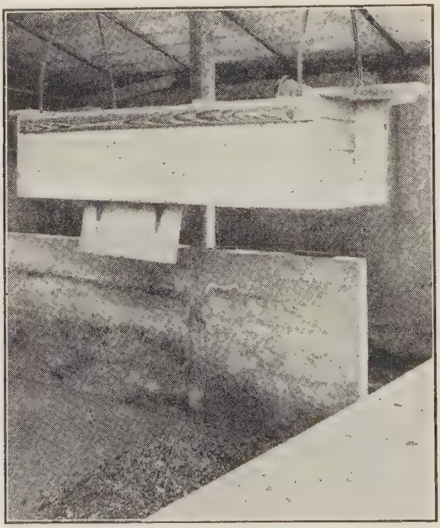

Fig. 135.—A litter carrier for transporting the manure from the droppings boards to the manure house or pit. (*Photograph by U. S. Dept. Agr.*)

Droppings-board Scraper.—The proper cleaning of the droppings boards is very important in keeping the laying house clean and sanitary. For this purpose a good droppings-board scraper is important, a good type being illustrated in Fig. 132.

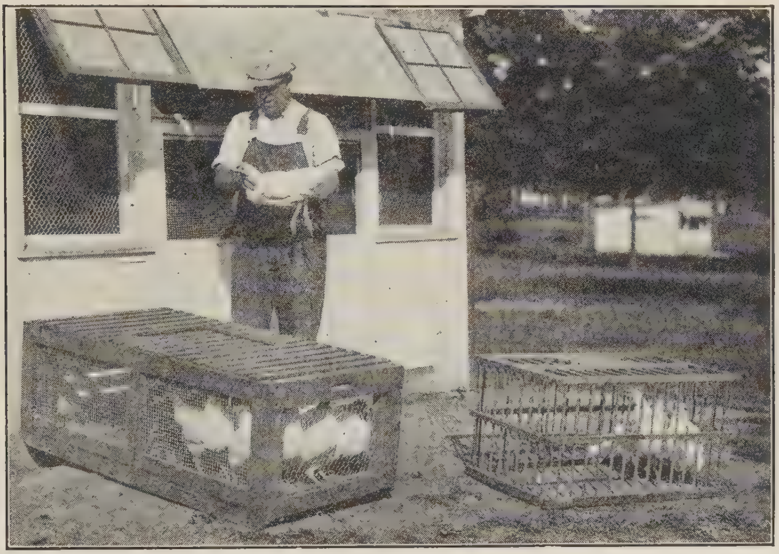

Fig. 136.—A crate for catching chickens. At each end there is a sliding door that can be raised and there is a sliding door in the top. (*Photograph by U. S. Dept. Agr.*)

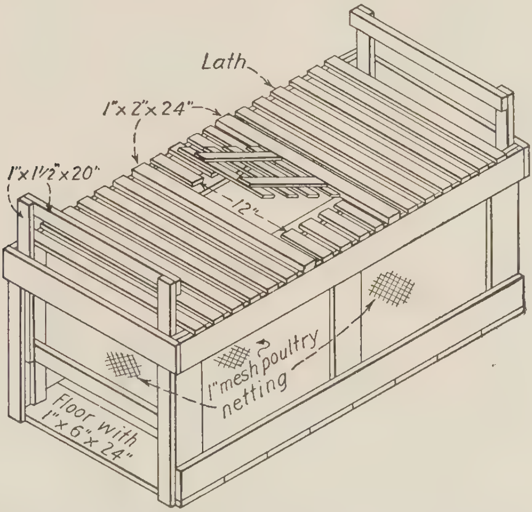

Fig. 137.—Poultry-catching crate, which is placed in front of the runway to the house. (*Plan by Kan. State Ext. Service.*)

Nests.—The nests should be constructed so that they may be cleaned readily, and there should be enough of them so that several hens do not crowd into one nest, in which eggs are liable to be broken. Boxes should not be used for nests because the corners tend to harbor lice and mites and are difficult to clean and disinfect properly. The most satisfactory type of nests is shown in Fig. 133. The hens enter the nests from the rear and the eggs are gathered by opening the door in front of the row of nests. This type of nests tends to prevent the development of the bad habit of egg eating.

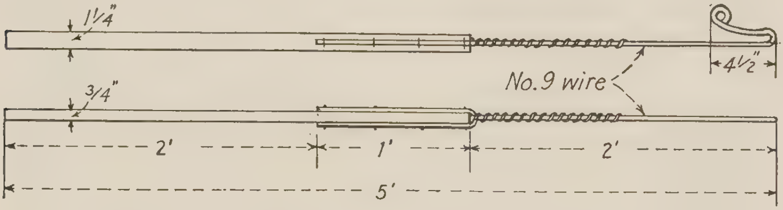

Fig. 138.—Method of constructing a catching hook. (*Calif. Agr. Exp. Sta.*)

When pedigree breeding work is carried on, trap nests are necessary. There are different styles of trap nests manufactured by various companies or trap-nest fronts may be purchased and attached to the nests. Trap nests should be made so that they may be cleaned readily, and they should be durable and well ventilated. The traps should be kept in perfect working order at all times. There should be one trap nest for approximately every four birds in the flock.

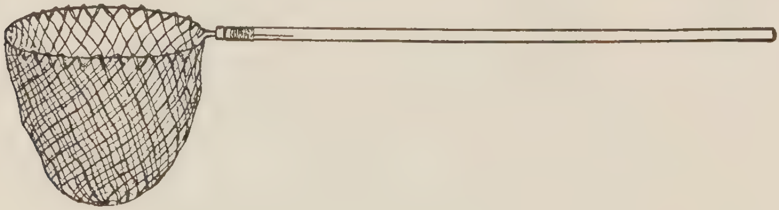

Fig. 139.—Net for catching chickens. (*Calif. Agr. Exp. Sta.*)

Egg Carriers.—On plants where several hundred eggs are gathered daily, special egg-carrying devices are often employed. They should be so constructed as to facilitate the collecting of the eggs and to avoid egg breakage (see Fig. 134).

Litter Carriers.—On many commercial poultry plants litter carriers suspended from overhead tracks are used in cleaning the laying houses and the droppings boards. Where the size of the plant justifies its use, the installation of a litter carrier is a good investment (see Fig. 135).

Broody Coops.—Coops for "breaking up" broody hens are necessary in all houses. The sooner that broody hens are broken from setting the sooner they come into laying condition again. The coop for broody hens should be so constructed that it may be cleaned readily and give the birds access to feed and water at all times. The coop should have a false bottom so that the droppings will not accumulate in the coop. Feed cups or troughs and water cups should be attached to the coop, because the broody hens should be fed and watered regularly in order to get them back into laying condition as soon as possible (see Fig. 133).

Selecting Crates.—For the proper selection of breeders and layers and non-layers, a good selecting crate is necessary, as illustrated in Fig. 136. A selecting crate should be strongly built, easily portable and so designed with movable ends and a sliding top door that it provides for the most efficient selection of birds (see Fig. 137).

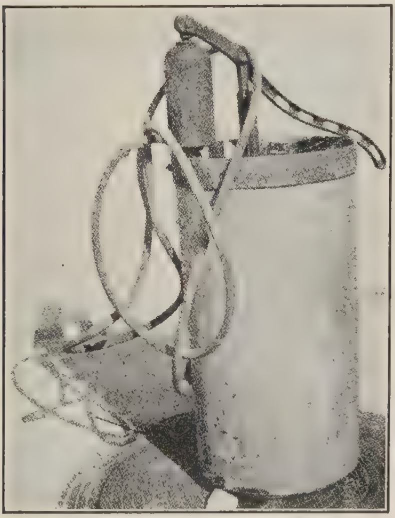

Fig. 140.—A spray pump is very useful for disinfecting poultry houses. (*Photograph by Ill. State Coll. Agr.*)

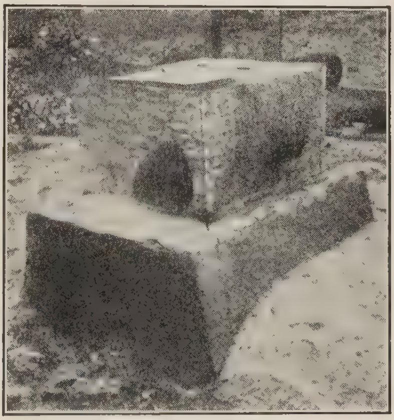

Fig. 141.—A good incinerator for the poultry farm. (*Photograph by N. J. Agr. Exp. Sta.*)

Catching Hook and Net.—When it is necessary to catch an individual bird, a hook, as illustrated in Fig. 138, or a net, as illustrated in Fig. 139, may be used. The catching net is preferable to the catching hook, because there is less danger of injuring the bird.

Spray Pump.—For the proper disinfection of brooder and laying houses a convenient and efficient spraying pump is necessary. A suitable pump is shown in Fig. 140.

Incinerator.—Diseased birds that are killed and dead birds should be burned; a good incinerator is illustrated in Fig. 141. Hudson (1928) discusses fully the proper construction of a practical incinerator for poultry plants; his paper should be read by all who have incinerators to construct.

CHAPTER XXI

NUTRITION

Practically all feeds for poultry are supplied either directly or indirectly by plants. Both plants and animals are composed of a great many chemical compounds, most of which fall into one of the following classes: proteins, carbohydrates, fats and minerals, all of which are often referred to as "nutrients." Plants obtain their nourishment from the soil, air, and water and prepare numerous chemical compounds which may be used by animals. Animals use the prepared nutrients for the purpose of forming new tissue, repairing worn-out tissue and supplying heat and energy for the purpose of maintaining body temperature and for carrying on all of the body activities.

> The activities on which the life of the body depends involve a continuous expenditure of energy and a constant exchange of material. Ultimately the body is dependent upon food for the fuel materials which supply energy, for the substances which are transformed in the body, and for those whose presence regulates and controls these transformations. The materials leaving the body are to be regarded not merely as wastes but as end products of an orderly and coordinated series of chemical reactions which occur in the body and by virtue of which its functions are performed. Thus the chief functions of food are: (1) to yield energy, (2) to build tissue, (3) to regulate body processes.
>
> These functions involve reactions which are dependent upon the chemical composition and constitution of the food. "The assemblage of processes concerned in the growth, maintenance, or repair of the living body as a whole, or of its constituent parts or organs" constitutes *nutrition* in the broader meaning of the term; therefore, any food constituent which takes part in any of these processes may be regarded as having nutritive value and serving as a nutrient (Sherman, 1927).[1]

In the production of energy, the building of body tissue and the regulation of the body processes, the requirements of the chicken depend upon whether growth, maintenance, fattening or the production of eggs is the objective.

Law of Diminishing Increment Applies.—The application of the law of diminishing increment in the growth of chickens and in egg production is discussed by Jull and Titus (1928).

> The rate at which an animal producing flesh for human consumption gains in weight, as expressed by the number of units of feed required for the successive unit increases in live weight, is a problem of considerable practical importance.

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[1] Sherman, Henry C., "Chemistry of Food and Nutrition." By permission of The Macmillan Company, publishers.

In the raising of poultry for market it is well recognized that beyond a certain stage in growth the value of the feed required to produce 1 lb. gain in weight of live animal is out of all proportion to the value of the gain. Hence there has developed the common practice of marketing growing poultry at from 8 weeks to about 8 months of age. So far as the authors are aware, however, no experimental work has ever been undertaken to determine precisely the relationship between growth and feed consumption in the domestic fowl.

In poultry husbandry there are several types of phenomena which involve a gradual decrease in the per unit effect of some causal factor as the quantity of the factor acting increases. One phenomenon illustrating this point is the annual decrease in the egg production of hens, which after three or four years is so great that few hens produce eggs enough to justify the feed consumed. At the U. S. Animal Husbandry Experiment Farm, Beltsville, Md., it was found that for a period of three years, with a small group of birds, the annual average egg production per bird was 236, 188, and 167 for the first, second, and third years, respectively. Egg production decreased each year, and assuming that laying hens consume approximately the same amounts of feed each succeeding year, it is obvious that egg production would soon become unprofitable. Brody, Henderson, and Kempster, in a rather large group of birds of two breeds, observed that each year's production was 88 per cent of that of the preceding year.

Another illustration of gradual decrease in the per unit effect of some causal factor as the quantity of the factor acting increases, may be cited in the results obtained at the U. S. Animal Husbandry Experiment Farm in feeding laying hens different quantities of protein. In rations in which the protein, except that contained in the grains, was provided exclusively from meat scraps, egg production increased as the protein level was raised, but above a protein level of 20 per cent egg production did not increase at the same rate as the protein level was increased. In other words, as the protein level was increased above the 20 per cent level there was relatively a decreasing rate of egg production.

In the growing of chickens the same principle applies; there comes a time when the rate of growth decreases although feed consumption may be on the increase. Available data indicate that the relationship between increase in live weight in growing chickens and increase of feed consumed is expressed by the law of diminishing increment. Though comparatively few data are available to test the application of the law in the case of growing chickens, a rather complete discussion of it in its application to cattle, hogs, and chickens is given by Spillman and Lang (1924). A very interesting feature of the law is that it provides for the calculation of the rate of gain per feed unit, and the number of feed units per pound of gain, in growing chickens and in chickens that are being fattened for market.

Growth.—Growth gives rise to increase in size; differentiation gives rise to change in shape, due to the fact that growth takes place more rapidly in some directions than in others, as explained in Chap. V.

Recent investigations upon nutrition in growth and in maintenance tend on the whole to the view that the same chemical substances are involved in both; but that in growth the needs for specific substances are accentuated. The amounts required in growth may be greater not only as compared with the size of the body but also compared with its total food requirement, and also the needs of the growing organism are more urgent so that a shortage of any essential factor becomes more quickly and strikingly apparent and is likely to be more harmful than in the case of the maintenance metabolism of the adult (Sherman, 1927).[1]

Problems related to the growth of chickens have been studied intensively by the Missouri Agricultural Experiment Station. Kempster and Henderson (1923) make the following pertinent observation:

> The rate at which a fowl grows is quite largely dependent upon environmental factors, such as temperature, sanitation, and suitable rations. If the weather is too cold, growth will be retarded, and if too warm food consumption will be less, with correspondingly slower growth. Sanitary houses and yards are of equal importance. The kind of ration and the method of feeding are also factors upon which growth is largely dependent. To secure optimum growth due attention must be paid to all these factors.

Brody (1927*b*, 1927*c*, 1927*d*) of the Missouri Agricultural Experiment Station has made a number of interesting observations regarding growth and development.

> The growth curve is divided into two principal segments, one of increasing slope (representing increasing time rate of growth) and the other of decreasing slope (representing decreasing time rate of growth). The junction between the two segments occurs in the animals examined when about one-third of the mature weight is reached, and in man when about two-thirds of the mature weight is reached. The age of puberty, and the age of the lowest specific death rate, coincides with the age of junction between the two segments. During the phase of growth following the junction, the percentage rate of growth with respect to the growth yet to be made is constant. The phase of growth preceding the inflection is made up of several segments, each of which represents a period of constant percentage rate of growth with respect to growth already made. Thus the growth curve is divided into two phases, one during which the percentage rate of growth is constant with respect to the growth already made, and another during which it is constant with respect to the growth yet to be made to reach the mature weight. The period of growth may be divided into two phases: (1) A self-accelerating phase during which the time-rate of growth increases with the increase of the size of the organism; and (2) A self-inhibiting phase during which the time-rate of growth decreases while the size of the organism increases. The present bulletin presents analyses of growth curves of the self-accelerating phase of growth. These analyses brought to light the following facts: (1) in warm-blooded animals this part of the curve is made up of several (4 or 5) segments apparently representing distinct stages of growth; (2) the percentage-rate of growth during each of these stages is constant; (3) each stage of constant growth rate passes into a succeeding stage of a lower, but constant, percentage-rate; (4) the passage from one state to the other is abrupt, the abruptness being of the order found in metamorphosis in cold-blooded animals.

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[1] Sherman, Henry C., "Chemistry of Food and Nutrition." By permission of The Macmillan Company, publishers.

In an analysis of curves of the self-inhibiting phase of growth, Brody demonstrates the fact that following the major inflection in the growth curve the time rates of growth decline by a constant percentage.

Factors Affecting Rate of Growth.—Henderson and Brody (1927) show that temperature exerts a profound influence on the percentage rate of growth of embryos and that this influence varies with the stage of incubation. That the rate of growth of the male chicken differs to a considerable extent from that of the female is shown by Jull (1923*d*), who found that males grew faster than females, a significant difference in rate of growth occurring at 8 weeks of age. Latimer (1924) has shown that the postnatal growth rate of the muscles, ligamentous skeleton, digestive tract, lungs, heart, kidneys, suprarenals and integument is of the same character as the growth rate of the body. Titus and Jull (1928) observed that although feeding sour skim milk has no marked effect on the calculated mature weights of Rhode Island Red chickens, the feeding of the milk accelerated growth during the first 15 to 18 weeks. From extensive studies in growth and development, Brody (1928) makes an important observation concerning growth in relation to various conditions of food supply.

> Additional comparisons are made between the age curves of growth of animals under several degrees of normality of food supply. The nearer the approach to an optimum food supply, the steeper is the age curve; that is, the more rapidly is the mature size approached, and the higher is the numerical value of the velocity constant of growth. The mature weight is also increased by the relatively improved food supply, but the relative increase in mature size is negligible as compared to the relative increase in the speed of approach to the mature weight.

Hogan, Shrewsbury and Kempster (1928) have shown that unusually rapid rate of growth in chickens is obtainable through the feeding of specially prepared rations. Kempster (1926*b*), from data collected from various sources, has shown, in Table 46, the extent to which growth rate varies among the different breeds of chickens and among groups of the same breed under different conditions of management.

Maintenance.

> Feeds are given to chickens in order that they may be converted into meat and eggs, but before this is possible the chicken must be maintained. Simply for maintenance the ration must furnish, among other things, fuel enough to maintain the body temperature and energy to carry on the vital processes. The normal temperature of the chicken is approximately 107° F. and some of the feed consumed must go to supply heat in order to maintain the normal temperature and also in order that the various body functions may be performed. The process of digesting feed, the movements which take place during respiration, the work performed by the heart, and the movements of the muscles all use up energy which must be replaced if life is to continue (Jull and Lee, 1927).

TABLE 46.—WEIGHTS ATTAINED BY BREEDS AND VARIETIES OF CHICKENS AT 12 AND 24 WEEKS OF AGE UNDER DIFFERENT CONDITIONS OF MANAGEMENT

(Kempster, 1926)

Source of data	Breed	Wt. at 12 wks.		Wt. at 24 wks.		
		Ckls., grams	Pullets, grams	Ckls., grams	Pullets, grams	Capons, grams
H. L. Kempster, Mo. Agr. Exp. Sta.	Barred Rocks	956	702	2,553	1,785	
	Buff Rocks	935	823	2,627	1,859	
	Rhode Island Whites	952	764	2,486	1,743	
	White Rocks	750	619	2,540	1,929	
H. H. Mitchell, L. E. Card, T. S. Hamilton, Ill. Agr. Exp. Sta.	White Rocks	716	602	1,636	1,403	1,849
A. G. Philips, Purdue Agr. Exp. Sta.	White Rocks	1,295	1,030	2,900	2,270	2,870
B. F. Kaupp, N. C. Agr. Exp. Sta.	Rhode Island Reds	1,045	880	2,490	2,017	
M. A. Jull, U. S. Dept. of Agr.	Rhode Island Reds[1]	880	725	2,560	1,880	2,539
	Rhode Island Reds[2]	1,321	1,049	2,650	2,075	2,783
H. H. Mitchell, L. E. Card, T. S. Hamilton, Ill. Agr. Exp. Sta.	Leghorns	882	740	1,716	1,380	
G. Davis Buckner, R. H. Wilkins, and Joseph H. Castle, Ky. Agr. Exp. Sta.	Leghorns	927	851	1,586	1,458	
L. E. Card, W. F. Kirkpatrick, Storrs Agr. Exp. Sta.	Leghorns	.....	819	.....	1,490	
H. G. May and N. F. Waters, R. I. Agr. Exp. Sta.	Leghorns	802	654	1,728	1,364	
	Hamburgs	457	384	1,015	812	
	Cornish	628	491	1,689	1,210	
	Brahmas	1,016	845	2,516	2,031	
L. E. Card, W. F. Kirkpatrick, Storrs Agr. Exp. Sta.	Rhode Island Reds	.....	1,040	.....	1,945	

[1] Not fed skim milk.

[2] Fed skim milk.

According to Gerhartz (1914) the feed requirements for maintenance in chickens is approximately the same per unit of body surface area as for other domestic animals.

In a series of experiments to determine the gross maintenance requirements of White Leghorn hens Titus (1928–1929) makes the following observation: "The gross maintenance requirement of White Leghorn hens, 16 months old and weighing, on an average, 1,632 g. was estimated as being 64 g. (of the special feed mixture used) per bird, per day during July." Titus also estimated that 40 g. of feed were required to produce an egg, the maintenance portion of the feed, therefore, constituting approximately 62 per cent of the total feed in the case of White Leghorns. Gerhartz (1914) and Voltz and Dietrich (1923) have shown that with hens in 50 per cent egg production, approximately 57 per cent of the total feed intake is required for maintenance.

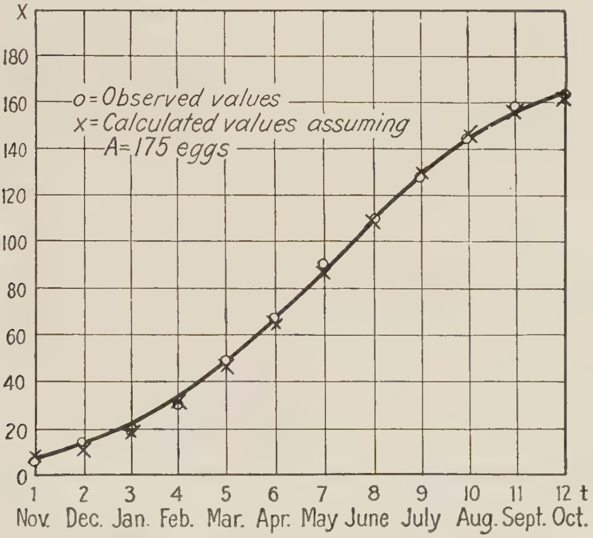

FIG. 142.—Curve showing the average number of eggs laid by White Leghorns at the Seventh Storrs International Egg Laying Contest. Ordinates represent the number of eggs laid (x) for the time (t); abscissæ represent the time (t) from November 1, the beginning of the observation, to any time of the year. (*After Brody*, 1921.)

Egg Production.—After the maintenance requirements of a laying hen are supplied, extra feed given her tends toward the production of eggs or fat, the number of eggs produced depending largely upon the genetic constitution of the hen. Brody (1921) from an analysis of the first-year records of production of 4,210 Barred Plymouth Rocks at the Maine Agricultural Experiment Station and 1,000 White Leghorns in the Storrs egg-laying contest, determined that egg production is of the same general order as the growth of organisms. The curve constructed by Brody is shown in Fig. 142, from which it is apparent that from the time that laying commences there is a methodical rate of production until cessation of first-year production.

Brody, Henderson and Kempster (1923) have shown that each year's egg production is 88 per cent of the preceding year's production, though Jull (1928) has shown that approximately 80 per cent is apparently a more representative figure for the average flock.

Fattening.—When a growing chicken or one which has reached maturity is supplied with a feed supply in excess of growth and maintenance requirements, respectively, it is inclined to deposit adipose tissue within or around the muscle tissue and the internal organs. Fattening consists in the formation of fat globules within the connective tissues, with the result that the dietary properties of poultry meat are enhanced.

THE NUTRIENTS

Chickens feed upon plants and animals and their products. Each natural product of the vegetable and animal kingdoms which serves as feed for chickens is an exceedingly complex mixture of chemical substances. For the sake of convenience these chemical substances are assembled into six fairly distinct groups: (1) water; (2) proteins; (3) carbohydrates; (4) fats and related compounds; (5) minerals; (6) vitamins.

Of these six groups of chemical substances, water is usually present in plant and animal organisms more abundantly than all others, and in some respects it may be regarded as constituting the basis of life. The other five groups are each composed of various chemical compounds, and, while each group tends to serve a specific purpose in nutrition, some chemical compounds of each of the five groups together with water are necessary to sustain life, promote growth and provide materials for egg production and fattening.

Water.—Water is a definite chemical compound composed of hydrogen and oxygen in the proportion of two parts of hydrogen to one of oxygen (H_2O). Water serves to soften the feed in the crop, preparing it for maceration in the gizzard, aids and takes a part in the processes of digestion and absorption, and dissolves the end-products of digestion to enable them to pass through the various membranes of the body. Water also serves in transporting the end-products of digestion from the digestive tract and accessory organs to all parts of the body. Waste products, through the aid of water, are transported from all parts of the body to the cloaca and thence to the anus. Since birds have no sweat glands, water serves to cool the body by evaporation through the air sacs and lungs.

Proteins.—The proteins all are qualitatively similar in that they contain nitrogen, carbon, hydrogen and oxygen, though they vary a good deal in their properties. "In spite of the variations which they show in chemical composition there is sufficient agreement to enable them to be placed in one class. The proteins contain from 50.6 to 55.2 per cent of carbon, 15.0 to 18.4 per cent of nitrogen, 6.5 to 7.3 per cent of hydrogen, 20.8 to 23.6 per cent of oxygen, along with 0.3 to 2.3 per cent of sulphur. In some cases phosphorus is found and in others a little iron" (Kellner, 1910).

The proteins are subdivided into three classes: (1) simple, (2) conjugated, (3) derived proteins. The simple proteins are those which yield, on hydrolysis, only amino-acids and their derivatives. Included in this class are egg albumin, serum globulin, glutenin from wheat, zein from corn and keratin from feathers. Conjugated proteins are substances that contain the protein molecule united to some other molecule or molecules otherwise than as a salt. Included in this class are the nucleoproteins present in the germs of the grains and in glandular tissue, vitellin of egg yolk and hemoglobin. The derived proteins include proteans, metaproteins, proteoses, peptones and peptides.

The proteins are broken down into simpler compounds by the action of strong acids or protein-splitting enzymes, the end-products being the amino-acids, some of which are: arginine, cystine, glycine, leucine, proline and tryptophan.

The proteins have been regarded in a general sense as tissue builders. "The muscles, which make possible the movements of the body, the nerves and brain, which control and direct all body activities, and also the various internal organs are chiefly composed of protein. Protein also makes up the cartilages in the body, the network of connective tissue throughout the muscles and organs, and such epidermal or outer tissues as the skin, hair, wool, feathers, hoofs, nails and horns. The bones also contain considerable protein." (Henry and Morrison, 1923.)

Carbohydrates.—The carbohydrates include those compounds which are formed of the three elements, carbon, hydrogen and oxygen, the latter two being in the proportion existing in water. The carbohydrates include sugars and starches together with the related products, the pentosans and celluloses.

The sugars are the simplest of the carbohydrates and include glucose or grape sugar, fructose or fruit sugar, sucrose or cane sugar, maltose or malt sugar and lactose or milk sugar.

Starch is much more complex in chemical composition than sugar, being formed by the union of many molecules of glucose, with the elimination of water. The reserve food material of most plants is stored chiefly as starch. It is insoluble in the sap of plants and before being utilized is converted into sugars by an enzymic action. An animal starch called "glycogen" is stored in the liver and muscles.

Pentosans are widely distributed in plants and are formed from pentoses in the same manner as starch is formed from glucose.

Cellulose occurs in plants but not in animals and is formed through the union of many molecules of glucose. Cellulose is the main constituent of the walls of cells in plants and is referred to as crude fiber in the feeding of animals.

Certain of the carbohydrates, especially glucose and probably maltose, serve important functions in poultry metabolism.

Fats.—There is a close relationship between fats and carbohydrates, and in the animal body the former may be derived from the latter. The proportion of oxygen is much less and of carbon and hydrogen much greater in fats than in carbohydrates. Fats, including oils, are compounds of glycerine with various fatty acids, such as stearic, palmitic and oleic.

Fats constitute the chief part of the adipose tissue of the animal body. While plants store their reserve food in the form of starch, animals store theirs in the form of fat or adipose tissue.

Minerals.—The mineral substances include calcium, phosphorus, sulphur, sodium, potassium, magnesium, iron, chlorine, copper and silicon, and they are found in both plant and animal tissues. Calcium is especially abundant in the skeletal structure of chickens and in egg-shell. The presence of calcium salts in the body is necessary for muscular contraction and calcium in the blood is essential for coagulation. Phosphorus is present in phosphoproteins, phospholipins, and nucleoproteins and in inorganic combinations particularly in blood and bone. Sulphur is present in a variety of combinations and is relatively abundant in the proteins of egg yolk and feathers. Sodium and potassium are widely distributed in plants and animals and are very important physiologically. Magnesium is widely distributed, having been found in the liver, kidney, muscle and bone. Iron has been found to be important in supporting plant and animal life because it is a constituent of hemoglobin, a protein present in red blood corpuscles. Chlorine, being present in combination with sodium and potassium in all body fluids and in the acid secretion of the proventriculus, contributes to the maintenance of the osmotic relations of the tissues. Copper has recently been determined to be of value in the feeding of animals. Silicon is present largely in the feathers. Calcium, phosphorus, sulphur and iron are used in the formation of the essential structures in the body. Iron, through its affinity for oxygen, is associated in carrying gaseous products and functions in the liberation of energy. Sulphur and phosphorus contained in protein substances give rise to sulphuric and phosphoric acids and these acids are neutralized by the alkaline carbonates and phosphates which serve as buffers for maintaining the proper acid-base equilibrium in the body. Again, the activity of enzymes, which function in building up and tearing down chemical compounds in the animal body, requires certain degrees of acidity or alkalinity which are maintained through the presence of mineral salts. "The control of both voluntary and involuntary muscles is accomplished through the proportion of calcium, magnesium, sodium and potassium salts acting upon them." Other functions of mineral salts are to serve in the movement of liquids throughout the body and its tissues, to facilitate vital processes involving the proteins, and to keep certain nitrogenous constituents, in solution, in the liquids of the body. Mineral chlorides furnish the chlorine of the hydrochloric acid in the gastric juice, pepsin being inactive except in the presence of hydrochloric acid.

Vitamins.—During recent years evidence has been accumulated that feeds must contain other substances than carbohydrates, fats, proteins and minerals in order that growth and reproduction may proceed normally. It has been demonstrated that normal nutrition depends upon the presence of certain substances, called "vitamins." Apparently they are required in very small quantities but their absence from feeds results in the development of various pathological conditions in animals known collectively as "deficiency diseases."

The vitamins are unique in two respects: first, their presence in feeds and their necessity for most efficient growth, maintenance of normal life processes and reproduction were not discovered until quite recently and, second, their chemical composition has not yet been determined. Through biological feeding tests, the existence of six or seven vitamins has been established, each having a specific effect on nutrition. It would not be surprising if the existence of still more vitamins may be determined by further studies on nutrition. The known vitamins are A, B, C, D, E, F, and G, although there is still some uncertainty concerning the identity of vitamin B as compared with vitamins F and G, which are derived from vitamin B.

Vitamin A.—Vitamin A, originally referred to as fat-soluble vitamin, is essential for growth and has a considerable influence on reproduction. When feeds given to chickens contain no vitamin A, certain characteristic changes take place in some of the body tissues, the most pronounced change occurring in the condition of the eyes. A condition develops called "xerophthalmia" (*xeros*, dry and *ophthalmos*, eye) and so vitamin A is often spoken of as the antixerophthalmic vitamin. Research work has demonstrated that growing animals require relatively abundant supplies of this vitamin, and, although the body has the power of storing it for future needs, additional supplies are necessary for reproduction (egg production). It is interesting to note that it is very abundant in many feeds rich in yellow pigment, although Palmer and Kennedy (1921) demonstrated that there is no correlation between the pigmentation of certain feeds and their vitamin-A content. Particular mention should be made of the fact that the fat of milk and the yolk of the egg are relatively rich in vitamin A and this suggests the importance of this vitamin in reproduction and in the development of young animals.

Vitamin B or F and G.—Vitamin B has been known as the water-soluble vitamin or the growth-promoting vitamin. Until recently it was regarded as a single substance, its complete absence in feeds resulting in the development of a disease in chickens called "polyneuritis" (*poly*, many and *neuritis*, inflammation of the nerves) which has symptoms similar to a disease in man called "beriberi." Since vitamin B prevents and cures polyneuritis, it has been referred to as the antineuritic vitamin. Recent work has demonstrated, however, that vitamin B, as it was formerly known, actually contains at least two individual vitamins, one of which possesses the antineuritic properties referred to and the other is a preventive of a disease in mammals called "pellagra." Just what relation the latter has to poultry has not been determined. The principal distinction between them, chemically, is in respect to their behavior toward heat. The antineuritic vitamin is fairly easily destroyed by heat, whereas the antipellagrous vitamin is quite stable.

Vitamin F stands for the antineuritic vitamin and vitamin G stands for the antipellagrous vitamin. At the present time, however, nutritional workers are not in agreement concerning the substitution of the letters F and G for B or retaining B for the antineuritic vitamin and using the letter F for the antipellagrous vitamin or using different designations. Kruse and McCollum (1929) discuss the various aspects involved regarding terminology, but for the present it is only necessary to consider the original vitamin B in its relation to poultry nutrition.

Vitamin C.—Vitamin C is known as the antiscorbutic vitamin because it is a preventive against a disease called "scurvy," which occurs among humans and some other mammals. Vitamin C is fairly abundant in oranges, grapefruit, raw cabbage, turnips and tomatoes, but, since poultry are not affected with scurvy, it is now generally conceded that vitamin C is not important in poultry nutrition.

Vitamin D.—Vitamin D is known as the antirachitic vitamin because its presence in sufficient amounts in feeds prevents the development of the well-known disease called "rickets," which is a form of improper bone development due to the lack of assimilation of proper amounts of calcium and phosphorus. The exposure of chickens to normal amounts of sunlight also has a pronounced effect on bone development. Chickens raised indoors under ordinary glass, however, usually develop rickets, unless their ration contains vitamin D or unless the ration has been subjected to ultra-violet irradiation. Rations thus treated acquire antirachitic properties, which is explained by Smith and Munsell (1929) as being "due to the presence in such food materials of a compound known as ergosterol, which becomes a powerful antirachitic agent on irradiation. Ergosterol is also present in the skin, and it is believed that this favorable effect of ultra-violet irradiation or exposure of the body to sunlight is due to the formation of vitamin D from the ergosterol in the skin. At present vitamin D thus occupies a unique position among vitamins in being the only one which is synthesized or manufactured from a definite chemical compound." The relationship between the antirachitic effect of the rays from the sun and from a mercury vapor quartz lamp is discussed by Tisdall and Brown (1927) and readers who desire more detailed information are referred to this and similar papers.

FIG. 142*a*.—A house used at the Animal Husbandry Experiment Farm, Beltsville, Md., for nutrition experiments with chicks in the lower half and laying hens in the upper half. (*Photograph by U. S. Dept. Agr.*)

The failure of normal deposition of calcium phosphate in the young bone is not to be attributed to fault of the bone tissue itself but rather of the fluid which bathes and feeds it; for Shipley found that a rachitic bone placed in normal blood serum begins at once to calcify normally; and Kramer and Howland showed that in rickets there is always a subnormal concentration of either calcium or phosphorus (or both) in the blood serum.

Since the normal concentration of calcium or phosphorus (inorganic phosphate) in the blood serum is essentially the maximum also, it follows that whenever the concentration of calcium or phosphorus or both falls seriously below the normal, the product of the concentrations of these two elements will fall below the normal product. The conception of an essential connection between the condition of rickets in the bone and the occurrence of a subnormal concentration-product of calcium and phosphorus in the blood serum, suggested by Kramer and Howland, has been both amplified and rendered more precise by the physicochemical investigations of Holt, LaMer, and Chown . . .

It has been fully demonstrated, especially in well-controlled laboratory experiments upon rats, that rickets may be induced or prevented at will in any of three ways, the experimental conditions being suitably chosen in each case: (*a*) by changes in the amounts and proportions of calcium and phosphorus supplied through the blood, (*b*) by the deficiency or the abundance of the antirachitic vitamin, (*c*) by the deficiency or the adequacy of the ultraviolet irradiation received (usually) either as direct sunlight or from a quartz mercury vapor lamp (Sherman, 1927).[1]

Gassman (1928) prepared the main constituent of bone synthetically through the action of sunlight in the presence of natural ice water which contains small amounts of phosphorus in the form of oxide. The natural and artificial phosphatocalcium carbonates are apparently identical in composition and properties. It is suggested that a study of its combining power with organic substances should throw some light on calcium metabolism and bone diseases.

Vitamin E.—Vitamin E is known as the antisterility vitamin because its absence in the rations of mammals causes sterility. Whether this vitamin is of importance in poultry nutrition has not been definitely determined as yet.

The Distribution of the Nutrients in Poultry Feeds.—The important part which plants play in supplying nutrients required by chickens is emphasized by Henry and Morrison (1923).

> It is Nature's plan that plants shall use energy supplied by the sun in building inorganic matter taken from earth and air into organic compounds. In this process the sun energy employed becomes latent, or hidden. Animals can not directly secure from the sun the energy necessary for their life but must live on the organic compounds built by plants. After more or less change during digestion, these compounds are built into their body tissues or are broken down within their bodies to produce heat and energy. In the coal burning in the grate, there reappears the energy of the sun which was stored in the plants of ages ago. In a similar manner the energy received from the sun by plants during their growth is transformed into animal heat and energy. Plants are thus sun-power machines for furnishing food to support animal life.

Plants alone, however, do not supply all of the nutrients in sufficient quantities for the various purposes for which chickens are fed. For many years proteins, carbohydrates, fats, mineral matter and water were recognized as the most important nutrients in plant tissues and were regarded as the fundamental factors in the diet of animals. Methods for the analysis of feeds were perfected and it was observed that there were pronounced differences in the composition of many of the feeds. Most of the cereal grains contain less protein than animal feeds, while certain of both of these kinds of feeds may be low in the amount of minerals they contain for certain purposes in the feeding of poultry. Many of the plants and their products have but small quantities of some of the vitamins. Also, there is frequently a marked difference in the quality of proteins from different sources.

It is realized now that feeding tests are necessary to determine the feeding value of any particular feed. Regarding the significance of a

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[1] Sherman, Henry C., "Chemistry of Food and Nutrition." By permission of The Macmillan Company, publishers.

TABLE 47.—AVERAGE COMPOSITION OF POULTRY FEEDS

Feed	Moisture, per cent	Ash, per cent	Crude protein, per cent	Carbohydrates		Fat, or ether extract, per cent
				Crude fiber, per cent	Nitrogen-free extract, per cent	
Grains and seeds:						
Barley	9.6	2.9	12.8	5.5	66.9	2.3
Barley meal	9.6	2.9	12.8	5.5	66.9	2.3
Bread	33.8	1.5	7.9	0.7	55.4	0.7
Brewers' grain (dried)	6.8	3.6	26.9	14.3	41.4	7.0
Broomcorn	11.8	2.9	10.2	8.2	63.5	3.4
Buckwheat	12.6	2.0	10.0	8.7	64.5	2.2
Buckwheat middlings	12.0	4.8	28.3	4.8	42.7	7.4
Coconut meal (O. P.)	7.3	5.5	21.3	9.4	46.5	10.0
Corn	12.9	1.3	9.3	1.9	70.3	4.3
Corn bran	10.3	2.4	9.9	10.4	59.7	7.3
Ground ear corn	15.6	1.5	8.3	6.8	64.4	3.4
Corn gluten feed	9.2	3.6	25.1	7.3	51.9	2.9
Corn gluten meal	9.0	1.3	40.9	3.2	44.5	1.1
Corn meal or chops	12.9	1.3	9.3	1.9	70.3	4.3
Cottonseed meal (prime)	6.9	5.9	38.8	12.2	29.4	6.8
Cowpeas	9.8	3.6	23.8	4.3	57.1	1.4
Durra	9.9	2.0	10.1	1.7	72.8	3.5
Feterita	11.1	1.5	12.5	1.7	70.1	3.1
Field peas	9.2	3.4	22.9	5.6	57.8	1.1
Flaxseed	9.2	4.3	22.6	7.1	23.2	33.7
Flour middlings	10.7	3.7	17.8	4.7	58.1	5.0
"Red Dog" flour	10.1	2.9	17.2	3.1	61.9	4.8
Garden peas	11.8	3.0	25.6	4.4	53.6	1.6
Hempseed	8.0	2.0	10.0	14.0	45.0	21.0
Hominy feed	8.3	2.9	10.9	4.6	65.5	7.7
Kafir	9.4	1.6	11.1	2.1	72.6	3.2
Linseed meal (O. P.)	8.9	5.4	34.5	7.7	36.7	6.8
Malt sprouts	7.8	5.7	25.9	12.4	46.9	1.3
Millet	10.8	3.6	12.1	8.4	61.0	4.1
Milo	10.7	2.8	10.7	2.4	70.5	2.9
Navy beans	13.4	3.6	22.7	5.8	53.0	1.5
Oats or ground oats	7.7	3.5	12.5	11.2	60.7	4.4
Peanuts (hulls on)	6.0	2.8	24.7	18.0	15.4	33.1
Peanut kernels	5.5	2.3	30.2	2.8	11.6	47.6
Peanut meal (no hulls)	6.2	4.9	49.3	6.3	22.5	10.8
Rice (polished)	12.3	0.5	7.4	0.4	79.0	0.4
Rye	9.5	1.9	11.1	2.1	73.7	1.7
Rye feed	10.2	4.0	15.6	4.3	62.7	3.2
Soybeans	6.4	4.8	39.1	5.2	25.8	18.7
Soybean meal	6.1	5.6	47.1	5.7	27.7	7.8
Shallu	9.7	1.6	12.5	1.7	71.1	3.4
Sunflower seed	6.9	3.1	16.1	27.9	21.3	24.7
Velvetbeans	9.8	3.1	26.2	6.0	50.1	4.8
Wheat	10.6	1.8	12.3	2.4	71.1	1.8
Wheat bran	9.6	5.9	16.2	8.5	55.6	4.2
Wheat flour	12.3	0.5	10.9	0.4	74.6	1.8
Wheat middlings (shorts)	10.1	3.5	16.3	4.3	61.6	4.2
Wheat screenings	10.2	3.9	13.3	7.4	61.1	4.1
Feeds of animal origin:						
Blood meal	9.7	3.3	82.3	....	3.8	0.9
Bone meal	7.2	61.5	23.1	3.3	....	4.9
Bone meal (steamed)	4.1	70.0	4.9	....	....	0.5
Buttermilk	91.0	0.7	3.0	....	4.8	0.5
Buttermilk, condensed	71.5	3.3	11.5	....	10.4	3.3
Buttermilk, dried	4.5	8.1	34.6	....	48.3	4.5
Fish meal	6.6	21.0	56.1	0.7	2.6	10.5
Fresh bone	30.4	21.1	19.7	....	3.8	25.0
Meat scrap (50 to 55 per cent protein)	7.1	21.1	53.9	2.2	5.0	10.7
Pork cracklings	5.0	2.3	56.4	....	4.1	32.2
Skim milk	90.6	0.7	3.2	....	5.2	0.3
Skim, milk, dried	4.7	7.3	37.0	....	50.0	1.0
Tankage	7.6	22.2	53.7	1.8	3.8	10.9
Whey	93.8	0.4	.6	....	5.1	0.1
Green feeds, etc.:						
Alfalfa (green)	72.9	2.6	4.7	8.0	11.0	0.8
Alfalfa-leaf meal	5.6	14.2	20.5	15.2	41.1	3.2
Alfalfa meal or alfalfa hay (dried)	8.3	8.9	16.0	27.1	37.1	2.6
Beet pulp (dried)	8.4	3.5	9.3	18.7	59.3	0.8
Cabbage	91.1	0.8	2.2	0.9	4.7	0.3
Cane molasses	24.5	6.8	3.1	....	66.1	....
Carrots	88.6	1.0	1.1	1.3	7.6	0.4
Kale	88.7	1.9	2.4	1.5	5.0	0.5
Mangels	91.2	1.0	1.4	0.8	5.4	0.2
Potatoes	78.9	1.0	2.1	0.6	16.3	0.1
Rape	85.7	2.0	2.4	2.2	7.1	0.6
Red-clover hay (dried)	12.9	6.9	13.6	24.1	39.1	3.4
Rutabagas	88.6	1.2	1.2	1.3	7.5	0.2
Turnips	90.6	0.8	1.3	1.2	5.9	0.2

chemical analysis of a feed, McCollum and Simmonds (1927)[1] make an interesting observation: "It seems remarkable, in the light of discoveries during the last few years, that close students of nutrition accepted without experimental proof for so long the belief that the results of a chemical analysis revealed the dietary values of food-stuffs." At the same time, a knowledge of the chemical analysis of poultry feeds is necessary in order to be able to choose feeds containing the required nutrients in greatest abundance. McCollum and Simmonds (1927) point out that "one of the great epochs in the development of the science of nutrition is that in which Voit (1881), in Germany, and Atwater and his associates (1895, 1906), in America, examined and tabulated in classified form the chemical composition of an extensive list of human foods. Shortly after this, agricultural experiment stations accumulated similar data concerning substances used for feeding animals." In Table 47 is given the average composition of most of the feeds used in feeding poultry, with the exception of several mineral feeds and a few feeds that are especially rich in certain vitamins.

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[1] McCollum and Simmonds, "The Newer Knowledge of Nutrition." By permission of The Macmillan Company, publishers.

CHAPTER XXII

DIGESTION AND METABOLISM

For the most part the nutrients of the various feeds used by poultry are rarely in a form capable of direct absorption into the system. Chemical changes must be produced to render the majority of the nutrients soluble and diffusible, these changes being brought about by the process of digestion, which is accomplished partly by mechanical and partly by chemical means.

The changes which feeds undergo within the digestive tract to prepare them for absorption and ultimate use in the development of new tissue, repairing body waste and as a source of energy are collectively known as *digestion*. Digestion is effected by certain enzymes, produced by glands in the different parts of the digestive tract of the chicken and by the bile, secreted in the liver. Bacteria present in certain parts of the intestinal tract may also be instrumental in the digestion of some of the nutrients of feeds. Then, again, in their course through the digestive tract the feeds are subjected to mechanical processes which tend to reduce them to a fine state of division in order that the nutrients may be attacked more readily by the digestive enzymes.

As compared with the structure of the alimentary tract of the mammal, that of the chicken is much less complex (see Fig. 14 and pp. 61 to 63). In the case of the chicken, the structure of the alimentary tract suggests that the digestive process is relatively rapid. Teeth are replaced by a gizzard. The genito-urinary apparatus is relatively simple in structure. The urine is not stored temporarily in the bladder as in mammals, but is conveyed directly from the kidneys through the ureters to the cloaca where it mixes with the fecal matter from the intestines. It is this situation, the mixing of the urine and the feces before being eliminated from the body, that constitutes the chief obstacle in the determination of coefficients of digestibility of feeds for poultry. Katayama (1924) found that the total urea nitrogen was very nearly 1.146 times the uric acid and ammonia nitrogen. Katayama has suggested a method for calculating the urinary nitrogen from the total excrement nitrogen and the uric acid and ammonia nitrogen. Titus (1928) suggests modifications of Katayama's formulæ for computing the fecal nitrogen and the percentage of fecal organic matter in samples of chicken excrement.

Davis (1927) made determinations of the nitrogenous constituents of hen urine and found that it contained 62.9 per cent of uric acid nitrogen, 17.3 per cent ammonium nitrogen, 10.4 per cent urea nitrogen, and 8 per cent creatine plus creatinine. "Since there probably is an unknown reabsorption of urea, creatine and creatinine in the cloaca, it is not feasible to calculate urinary nitrogen from the uric acid in the droppings."

Considerable progress in determining digestion coefficients has been achieved and the digestion coefficients of a number of poultry feeds have been determined by numerous investigators. Before these are discussed, however, it is advisable to review briefly the various processes of digestion that the nutrients of feeds undergo in their passage through the digestive tract.

THE PHYSIOLOGY OF DIGESTION

It has already been observed that the nutrients of feeds are digested partly by mechanical and partly by chemical means. With respect to the mechanical aids to digestion, it should be observed that the outstanding features in the case of chicken are: the absence of mastication, the storage of food in the crop, and the grinding of feeds in the gizzard. The chemical means employed in digestion consist primarily in the breaking down of the proteins, carbohydrates, fats and minerals by enzymes.

Mechanical Processes.—The mechanical processes through which feeds pass are for the purpose of making the nutrients more readily available to be acted upon by the enzymes. The storage of feed in the crop serves the purpose of softening the feed by being thoroughly mixed with water. The complete digestion of feed would not be possible were it not for the fact that the feed is broken down into minute particles through the powerful grinding action of the gizzard. The grinding power of the gizzard is indicated from the observations of Reaumur (1750) and Spallanzani (1784) as noted on page 62.

Grinding the Feed.—The function of grit in the form of small stones in the gizzard has been investigated by Mangold (1906, 1925, 1927) and Mangold and Feldin (1909). Klee (1906) was led to believe that the presence of grit in the gizzard was necessary for the maintenance of birds in the best of health, and Mangold reports that "The presence of sand and small stones allows poultry to derive more benefit from their food when this is based on grain." Jull (1915*b*) conducted a number of experiments to determine the value of grit in feeding chickens and concluded that "Final deductions, therefore, point to the practical necessity of grit for the economical digestion of whole grain." Halnan (1924–1925*b*), after conducting a number of experiments, came to the conclusion that the efficiency of the gizzard as a grinding organ is considerably enhanced by the presence of grit. K. Krüger (1925) conducted digestion trials and was led to believe that the presence of grit in the gizzard facilitated the process of digestion.

Buckner and Martin (1922) make the following observation:

> It is the belief of the authors that its normal food supply furnishes to the wild fowl all of the necessary calcium and other materials for the production of its relatively small number of eggs, but that the addition of grit becomes necessary to its domesticated descendant to hasten the digestion of large quantities of food and thus supply the large quantities of nutriment and other materials necessary in the intensified egg laying brought about by man for his own purposes. And finally this opinion is further justified by the fact that there is not an instance in the animal kingdom known to the authors where an external inanimate object is essential for their normal physiological processes.

Jaeckel (1924) found that the power of gizzard contraction remains the same when the gizzard contains stones and when they are absent, but he also found that fowls were kept in better physical condition when the gizzard contained stones. On the other hand, where growing chicks and laying hens are fed ground grains exclusively, it would appear that grit is not so essential, at least according to the observations of Carrick, Hauge and Prange (1927) and Kennard and Bethke (1927*a*).

Chemical Processes.—The chemical processes to which feeds are subjected while passing through the digestive tract are numerous and only the more important ones can be considered in this brief review. In the mouth the saliva contains ptyalin but the food passes from the mouth to the crop so quickly that there is probably little opportunity for the process of digestion to proceed to any material extent. Teichmann (1899) reports that no evidence was afforded that the crop secreted any digestive ferment. While the food is in the crop, however, it is acted upon by the ptyalin, a starch-digesting enzyme, which, according to Shaw (1913), is present in the saliva one hour after hatching. Ptyalin converts starch first into dextrin and maltose and then into glucose.

Klug (1890) has reported that he found traces of acid and pepsin in the crop, derived from the proventriculus, although Shaw (1913) reports that the crop contains no enzyme. Hamilton and Mitchell (1924) found lactase in the crop. The reaction of the crop becomes acid due to the presence of lactic acid, as shown by Teller and Schwartz (1923).

The semifluid mixture of feed passing from the crop to the proventriculus is made acid by the hydrochloric acid secreted by the cells of the proventriculus. This acid destroys the ptyalin in the saliva but activates the pepsin of the proventriculus. Teichmann (1899) reports that the function of the proventriculus seems to be to secrete pepsin and hydrochloric acid. The pepsin splits the protein to peptones. Shaw (1913) observes that "By the second day the stomach of the chick secretes a gastric juice which contains proteolytic and curdling ferments (enzymes) active in acid medium."

From the proventriculus the feed is passed to the gizzard where, although no digestive enzymes are produced, according to the observations of Shaw (1914), the process of digestion is continued by the action of the gastric juices, this process being facilitated by the grinding action of the gizzard.

From the gizzard the partially digested feed passes into the duodenum where the pancreatic juice comes into play. Bernard (1856) and Langendorff (1879) as well as Paira-Mall (1900) studied the influence of the pancreatic juice on digestion. According to Shaw (1913) the pancreatic juice contains proteolytic, amyloytic and lipolytic enzymes which act best in a slightly alkaline medium. These enzymes act on protein. starch and fat. The peptones are acted upon as well as any proteins that may have escaped digestion in the proventriculus. Starch is broken down into maltose and then dextrose. The fats are split into glycerine and fatty acids.

In the duodenum the feed comes into contact with the alkaline bile, which though it contains no enzymes, aids the pancreatic juice in various ways, especially in emulsifying the fats so that the enzymes in the pancreatic juice may act on them more readily.

The juices which are secreted by the walls of the small intestine contain certain enzymes which aid the pancreatic juice to digest proteins and carbohydrates. An enzyme of particular importance secreted by the glands of the intestinal wall is erepsin, which completes the digestion of protein. Milk sugar is broken up by bacteria. Röeseler (1928) says that the ceca serve for the digestion of cellulose with the aid of bacteria and that every 24 to 28 hr. they discharge a secretion quite different from other secretions of the digestive tract.

This brief review of the physiology of digestion deals with the digestion of the proteins, carbohydrates and fats preparatory to their absorption into the system. The manner in which minerals are utilized is but little understood at the present time though some work has been done in regard to mineral metabolism, which is discussed on page 179. As far as the digestion of the various nutrients is considered, however, it should be understood that the present discussion deals essentially with the various processes of digestion of the nutrients in preparing them for absorption.

Although the metabolism of proteins, carbohydrates, fats and minerals is dealt with later, it should be realized that the presence of the various vitamins is of particular importance in determining the absolute value of many poultry feeds.

It should be realized, also, that certain products of the endocrine glands, such as the thyroids and parathyroids, may exercise considerable influence on the physiology of digestion. As yet, however, aside from the work of Crew and Huxley (1923), working with thyroid, Hogben

(1924) working with desiccated extracts of corpus luteum, suprarenal cortex and pituitary, Crew (1925*b*) and Szuman (1926*b*) in studies on the influence of the gonad on metabolism and Cole and Hutt (1928), working with thyroid, very little has been done to determine the influence of the various endocrine products on the physiology of digestion.

METABOLISM

The changes which the nutrients of feeds undergo in their passage through the digestive tract are necessary in order that the digested nutrients may be absorbed by the body. The changes which take place after the digested nutrients have been absorbed are included under the general term "metabolism."

The digested nutrients are used by the body for the purpose of maintaining body temperature, supplying energy and the development of tissue, fat or eggs.

Heat Requirements.—The temperature of the normal hen is approximately 107° F. and since this temperature is usually higher than that of the surrrounding atmosphere, the chicken's body is continually losing heat, which is made good by heat obtained from the absorbed nutrients of the feed.

Energy Requirements.—Energy is required for the movements which take place during respiration, for the work performed by the heart, for the movements of the muscles and for other activities. The only source of energy to the body is the nutrients of the feed.

It is, in fact, an essential condition of life that heat and energy should be generated in the body itself, and it is in the living cells of the organism that they are produced from the digested nutrients which are brought in the blood supply to all parts of the body, and there taken up by the cells. Heat and energy, then, are only generated in the animal body by the decomposition and combustion of organic materials which the cells have received from the blood. The combustion is preceded as a rule by a splitting up of the compounds, probably under the influence of enzymes. Simpler substances are obtained in this way, and they are oxidized by means of the oxygen in the blood. The fine blood vessels of the lungs take up the oxygen, which is drawn in with each breath of air, and transport it in the blood through the whole body.

Whenever energy or heat are to be generated this oxygen unites with the substances which have been prepared for the combination by a preliminary cleavage. The nitrogen-free substances—such as carbohydrates, fats, and organic acids—yield therby carbon dioxide and water, which are the same products as those formed when ordinary combustion takes place outside the body.

In a similar manner to that by which oxygen is brought to the cells, but in the opposite sense, the carbon dioxide is dissolved in the blood, reaches the lungs, and is there given out to the air, only a small proportion being excreted by the skin and intestine. The proteins and amides also give carbon dioxide and water on decomposition, as well as nitrogenous waste products, of which urea is the chief. [In birds the chief nitrogenous waste product is uric acid.] The latter, together with soluble salts and some of the water, are brought in the blood to the kidneys, and from there pass in the form of urine to the bladder. [In poultry the urine is excreted with the feces, as noted in the previous chapter.] There are other ways, too, in which water, whether from the food, drink, or the combustion of organic substances in the cells, leaves the body. Some is exhaled as gas from the lungs and skin, whilst the rest is got rid of in fluid form in the urine or feces.

The materials taken up by the blood from the alimentary canal are not always split up and oxidized, but when the food supply is liberal they are changed into body tissue or [eggs]. Hereby there arise as a rule many waste products, which are capable of further oxidation with the formation of the final products already mentioned.

All these changes, which take place from the entrance of the digested compounds of the food into the blood up to the excretion of the final products, are grouped under the term "metabolism." (Kellner 1910.)[1]

ABSORPTION

The digested nutrients are absorbed for the most part in the duodenum and in the remainder of the intestinal tract. There is some evidence, however, that the caeca play some part in digestion. Mangold (1925) is authority for the statement that the digested nutrients are all absorbed before they reach the rectum. Sharpe (1912) points out that the rectum serves in the absorption of water from the urine as it is delivered from the kidneys by the ureters. Weiner (1899) noted that when an artificial anus was provided, preventing the absorption of water by the rectum, unusually large quantities of water were consumed.

The proteins are digested by pepsin, trypsin and erepsin and become broken down into amino-acids, which are absorbed by the small intestine. According to K. Krüger (1925), no amino-acids are absorbed beyond the small intestine. They pass into the blood streams and are then carried into the general circulation, where they reach the various tissues of the body.

The glucose formed from the digestion of starch and sugar is rapidly absorbed by the intestinal wall and is taken up by the blood and carried to the liver and muscles where it is stored as glycogen. When the food is rich in carbohydrates, however, the liver and muscles cannot store all of the glucose as glycogen. The excess of sugar is changed to fat and is stored as such, and the stored-up glycogen is used to produce energy. The role of carbohydrates is not limited to the production of energy since they are are also sources of heat.

The fatty acids and the glycerin which are the end-products of the digestion of fat in the feed are reconverted into fat, and the fat is then absorbed and enters the blood stream.

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[1] Kellner, O., "The Scientific Feeding of Animals." By permission of The Macmillan Company, publishers.

The absorbed nutrients, on being transferred to the tissues of the body, may be oxidized to produce heat or energy or they may be transformed into body tissue or eggs. Henry and Morrison (1923)[1] state:

> The sugars may be converted into fats and stored as body fat, as may also the fats derived directly from the food fats. The amino acids may be built up into body protein or, if not needed for this purpose, a portion of their carbon, hydrogen, and oxygen may be converted into fat, while the nitrogen is excreted, chiefly in the form of uric acid. The highest use of the proteins, however, is the formation of nitrogenous tissues—the muscles, brain, nerves, skin, hair, and various organs of the body.

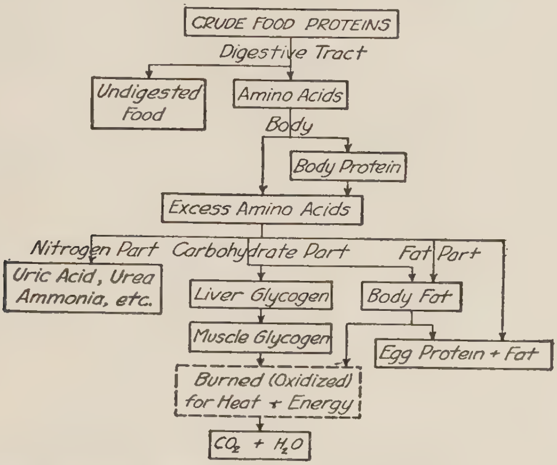
CRUDE FOOD PROTEINS
Digestive Tract
Undigested Food
Amino Acids
Body
Body Protein
Excess Amino Acids
Nitrogen Part
Carbohydrate Part
Fat Part
Uric Acid, Urea Ammonia, etc.
Liver Glycogen
Body Fat
Muscle Glycogen
Egg Protein + Fat
Burned (Oxidized) for Heat + Energy
$CO_2 + H_2O$

FIG. 143.—Scheme illustrating the use of proteins in the body. (*After Holst and Newlon*, 1927.)

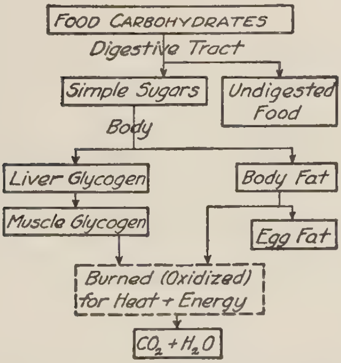
FOOD CARBOHYDRATES
Digestive Tract
Simple Sugars
Undigested Food
Body
Liver Glycogen
Body Fat
Muscle Glycogen
Egg Fat
Burned (Oxidized) for Heat + Energy
$CO_2 + H_2O$

FIG. 144.—Scheme illustrating the use of carbohydrates in the body. (*After Holst and Newlon*, 1927.)

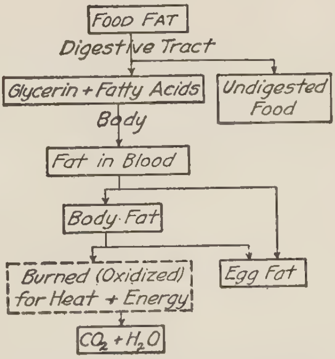
FOOD FAT
Digestive Tract
Glycerin + Fatty Acids
Undigested Food
Body
Fat in Blood
Body Fat
Burned (Oxidized) for Heat + Energy
Egg Fat
$CO_2 + H_2O$

FIG. 145.—Scheme illustrating the use of fats in the body. (*After Holst and Newlon*, 1927.)

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[1] HENRY and MORRISON, "Feeds and Feeding." By permission of The Henry Morrison Company, publishers.

The manner in which proteins, carbohydrates and fats are utilized in the body is shown in Figs. 143, 144, and 145, from Holst and Newlon (1927).

COEFFICIENTS OF DIGESTION

Some feeds are readily digestible and yield only a small amount of waste, while others, although theoretically containing all the requirements of economical feeds, may be quite unsuitable for poultry feeding purposes because the chicken may not be able to utilize the nutrients to good advantage. For this reason it is just as important to know how any feed is digested and how much of it is digested as it is to know how much protein, carbohydrates, fats and minerals are contained in the feed given. The vitamin content of a feed has been demonstrated to be of considerable significance in the feeding of chickens under certain conditions but aside from this it is important to know the extent to which the proteins, carbohydrates, fats and minerals of a feed may be digested by the chicken.

The percentage of each nutrient digested is termed the "digestion coefficient" or the "coefficient of digestibility" for that nutrient in the feed. Coefficients of digestibility, however, are more properly called "coefficients of apparent digestibility." Holst and Newlon (1927) give a simple illustration of the determination of the digestibility of the nutrients of feeds.

> Although analyses of composition are of great importance, of still greater importance to the practical feeder is the digestibility of the feed. Such information can be obtained only by actual feeding tests under carefully controlled laboratory conditions.
>
> In these tests definite amounts of an analyzed food are given to an animal and the corresponding excretions are analyzed. The nutrients fed and not excreted in the feces are accepted as the actually digested food. In this way, therefore, the *digestible matter* is determined, which again makes possible the computation of the *digestibility coefficients*. These give the number of parts digested, that is, the parts available to the body, of each 100 parts of the particular nutrient fed.
>
> Example: Katayama (1924) found as the average of three experiments with wheat bran fed to poultry, the following digestibility coefficients:
>
> | Organic Substance | Protein | Carbohydrates | Fat | Crude Fiber |
> |---|---|---|---|---|
> | 55.3 | 64.3 | 61.2 | 55.6 | 0 |
>
> These figures simply mean that of each 100 parts of organic substance (gross weight of every feed less moisture and mineral content) in wheat bran fed to poultry, 44.7 parts by weight were regained from the feces, *i.e.*, wasted. Consequently only the remaining 55.3 parts were retained by the body, that is to say, digested. Therefore the digestibility coefficient of the organic substance of

wheat bran for poultry is 55.3. It is low because of the large amount of crude fiber and pentosans it contains. The corresponding figure for the protein part of bran was 64.3; carbohydrates 61.2; and fats 55.6.

Research work dealing with the determination of the digestion coefficients of nutrients in poultry feeds is quite extensive and probably dates from that done by Sace (1845). Voit (1863) demonstrated the absence of a respiratory exchange of nitrogen in the dove and Weiske and Mehlis (1878) found that crude fiber is not digested by hens. Kalugin (1896, 1897) conducted experiments on the digestibility of millet, peas, buckwheat, wheat and barley in hens and Grost (1900), as reported by Knieriem (1900), investigated the digestibility of oats, barley and rye. Fields and Ford (1900) conducted experiments designed to study in poultry the digestibility of Kafir corn, Indian corn and cowpeas. Lehmann (1901) conducted digestion experiments with wheat and peas, using an artificial anus established in the abdominal wall.

The more recent research work pertaining to the digestibility trials of poultry feeds is summarized by Ackerson (1926):

> Brown (1904) tabulated the existing data on digestion trials with poultry and pointed out the difficulties to be encountered in arriving at digestion coefficients with fowls.
>
> Chief among these difficulties is that the urine and feces are excreted together. Various means have been employed to overcome this obstacle to a direct determination. Brown (1904) and Bartlett (1910) used a collection bag, while Fields and Ford (1900) collected the excrement in removable trays in the bottom of wire cages. Kalugin (1896) used large wooden cages lined with oil cloth in his work.
>
> On the other hand, Lehmann (1904), Paraschtschuk (1902), Kossa (1906), Völtz and Yakuwa (1909) and Szalagyl and Kriwuscha (1914) established a preternatural anus to permit the separate collection of the urine and feces.
>
> More recently Katayama (1924) subjected the above method to a critical study. He concluded that the digestibility of feeds can be obtained from the excrement of normal hens by applying factors to the various fractions of the mixed feces and urine, thus making the operation unnecessary.
>
> The method of Thomas (1919) of measuring the "biological value" of a protein has been adopted by Mitchell and his co-workers (1923) in extending the investigations of Nevens (1921) at that station. In this connection Mitchell (1924) states: "The only conceivable indirect method of measuring the urinary nitrogen of endogenous origin is to eliminate entirely the exogenous catabolism by the feeding of a nitrogen-free diet, and ensuring that enough of such a diet is consumed to provide energy for the requirements of the experimental animal, thus preventing the oxidation of body tissue for this purpose, with its inevitable loss of body nitrogen not properly included in the endogenous nitrogen that it is desired to measure."

Summaries of the digestibility of various poultry feeds are given by Brown (1904), Bartlett (1910) and Lindsey and Beals (1919). The more extensive series of digestion experiments with poultry have been carried out by Brown (1904), Bartlett (1910), Kaupp and Ivey (1923) Katayama (1924) and Fraps (1928). The average coefficients of digestibility of quite a number of poultry feeds have been compiled by Fraps (1928) and are given in Table 48.

TABLE 48.—AVERAGE DIGESTION COEFFICIENTS OF POULTRY FEEDS (Fraps, 1928)

	Protein	Fat or ether extract	Carbohydrates	
			Crude fiber	Nitrogen-free extract
Alfalfa leaf meal (2)*	99.7	0	3.5	0
Alfalfa meal (2)	63.4	21.8	1.4	34.4
Barley (21)	72.0	58.1	†10.4	82.1
Bran, corn meal, gluten feed, beef scraps (5)	78.6	74.7	....	51.4
Bran, corn meal, linseed meal, beef scraps (3)	75.3	78.5	0	46.7
Bran, corn meal, linseed meal, gluten feed (6)	77.3	68.8	....	39.6
Blood meal (6)	91.4	46.3	17.5	47.7
Buckwheat (12)	61.2	86.3	10.1	83.9
Buttermilk, dried (5)	81.6	78.6	....	81.1
Clover and corn meal (3)	71.8	66.7	10.4	61.6
Corn, corn chops, corn (cracked) (24)	74.9	85.1	14.8	90.1
Corn meal (11)	71.8	91.6	15.2	91.9
Corn meal (bolted) (5)	74.0	86.3	4.8	88.2
Corn meal (unbolted) (3)	73.5	84.5	6.8	87.7
Corn and corn meal, bolted and unbolted (42)	73.6	86.9	13.2	90.2
Corn meal 7 parts, beef scraps 1 part (5)	82.3	73.9	....	91.7
Corn meal and beef scraps (2)	90.0	94.5	....	77.4
Cottonseed meal (8)	76.1	86.2	11.9	85.7
Cowpeas, cowpea meal (8)	48.4	87.9	10.9	86.2
Darso (6)	36.0	85.6	37.7	88.9
Feterita (10)	87.8	80.7	33.2	91.3
Fish scraps, dried fish, fish meal (11)	90.7	95.7	....	15.4
Getrocknete gemuse (2)	81.9	27.1	0	69.3
India wheat (3)	75.0	83.8	20.9	83.4
Kafir (grain) and kafir meal (17)	66.8	78.1	18.0	91.7
Meat meal, bone meal, and meat and bone meal (7)	86.7	93.1	24.0	34.0
Millet (2)	76.1	77.9	16.9	87.0
Milo (12)	83.3	77.5	31.2	91.5
Oat groats (11)	76.7	88.6	13.6	90.5
Oats, whole (21)	74.1	81.7	7.1	69.3
Peanut meats (5)	80.3	78.4	4.1	84.2
Peas (3)	88.1	81.2	9.2	87.1
Peas and cowpeas	59.2	86.1	10.4	86.4
Potatoes (7)	46.9	0	6.4	84.5
Potatoes and oats (2)	54.6	49.4	6.8	92.5
Potatoes, rye and starch (2)	48.0	−33.4	6.3	83.5
Potatoes, sweet (3)	0	24.7	4.3	77.3
Rice bran (9)	57.9	87.1	3.0	52.3
Rice (brown((2)	84.1	87.9	6.5	98.1
Brown rice and clover (3)	77.8	38.8	5.6	88.9
Rice polish (4)	80.9	94.8	4.3	89.3
Rice polish (2)	79.1	4.6	33.1	98.3
Rice, rough (10)	74.2	72.2	5.1	83.8
Rye (8)	65.3	31.4	12.2	86.0
Shallu (3)	77.8	84.6	39.4	93.8
Sorghum seed (7)	16.0	84.1	15.2	88.0
Soy bean (2)	69.9	93.0	52.6	76.4
Soy bean oil meal (5)	83.3	81.4	2.2	83.2
Soy bean oil cake (8)	83.3	82.4	0	80.2
Tankage and tankage digester (4)	85.3	95.9	4.0	43.5
Tankage and oil meal (11)	86.2	94.1	19.6	45.6
Wheat middlings 6.25 per cent fiber (9)	50.0	52.6	9.0	49.7
Wheat gray shorts (4)	69.2	85.2	13.0	71.0
Wheat bran (11)	59.9	50.0	7.9	54.1
Wheat (34)	74.0	47.1	8.7	88.9
Wheat middlings 8.5 per cent fiber (9)	76.2	52.6	8.2	59.6

* The number given with each feed means the number of analyses made.

† Sokolowska (1923), in experiments dealing with the digestibility of the fiber, observed that it was entirely undigested.

Among other things, it has been determined by a number of investigators that chickens cannot digest crude fiber. Fraps (1928) observes that: "Ruminants have, on an average, a higher digestive power than poultry. The difference is greater for crude fiber which is almost indigestible for poultry." The differences are given in Table 49.

TABLE 49.—COMPARATIVE DIGESTION COEFFICIENTS FOR POULTRY AND FOR RUMINANTS

(Fraps, 1928)

	Protein	Ether extract	Crude fiber	Nitrogen-free extract
Alfalfa, 35 per cent fiber, poultry	63.4	21.8	1.4	34.4
Alfalfa, over 33 per cent fiber, ruminant	69.3	32.3	46.4	68.8
Barley, (whole), poultry	72.0	58.1	10.8	82.1
Barley, grain, ruminant	80.3	78.6	58.7	91.8
Corn and corn meal, poultry	73.6	86.9	13.2	90.2
Corn meal and chops, ruminants	64.1	88.4	30.6	92.3
Cottonseed meal, poultry	76.1	86.2	11.9	85.7
Cottonseed meal, ruminants	84.4	96.4	28.0	64.4
Feterita, poultry	87.8	80.7	33.2	91.3
Feterita, ruminants	76.5	73.7	16.7	91.5
Kafir (grain or meal), poultry	66.8	78.1	18.0	91.7
Kafir, balanced ration, ruminants	72.6	76.8	26.0	88.8
Millet, poultry	76.1	77.9	16.9	87.0
Millet, ruminants	68.3	87.3	25.6	90.6
Milo, poultry	83.3	77.5	31.2	91.5
Milo, ruminants	76.9	89.2	36.2	90.1
Oats, whole, poultry	74.1	81.7	7.1	69.3
Oats, 10–12 per cent fiber, ruminants	79.0	86.4	41.6	81.9
Peanut meats, poultry	80.3	78.4	4.1	84.2
Peanut meal, ruminants	88.8	95.2	37.2	83.8
Rice bran, poultry	57.9	87.1	3.0	52.3
Rice bran, ruminants	69.3	82.8	22.6	75.6
Rice polish, poultry	80.9	94.8	4.3	89.3
Rice polish, ruminants	67.9	85.9	14.9	92.2
Rice, rough, poultry	74.2	72.2	5.1	83.8
Rice, rough, ruminants	75.6	76.2	10.4	90.7
Wheat gray shorts, poultry	69.2	85.2	13.0	71.0
Wheat gray shorts, ruminants	83.9	87.2	17.6	90.8
Wheat bran, poultry	59.9	50.0	7.9	54.1
Wheat bran, ruminants	78.4	69.8	30.4	72.2
Wheat, poultry	74.0	47.1	8.7	88.9
Wheat, ruminants	81.9	77.4	55.3	45.0

THE RATE OF DIGESTION

The rate at which feeds are digested by chickens is of interest from the standpoint of the manner in which it may be affected by the kind and amount of feed given. Water is known to pass through the digestive tract much more quickly than solids. Also, certain solid feeds are much more readily digested than others.

The earliest work in determining the rate of digestion is that of Weiske (1878). More work was done by Brown (1904), Völtz and Yakuwa (1909) and Brown (1922). Using the method discarded by Brown, Kaupp and Ivey (1923*a*, 1923*b*) fed a mash colored by lamp black and drew the following conclusion:

> Digestive processes of the fowl are rapid. The greatest rapidity is shown in the laying and in the growing fowl, food passing on an average of 3 hr. and 52 min. in the case of growing fowls and 3 hr. and 46 min. in the case of the laying hens. Next in activity comes the adult hen not in laying condition, averaging 8 hr., and then the broody hen required an average of 11 hr. and 44 min.

Brown (1904) and Schwarz and Teller (1924) made observations on the retention of feed in the crop; the results going to show that larger amounts of feed require a longer time to leave the crop but that there are considerable variations in respect to the time which the various grains remain in the crop. The longer the grain remains in the crop the more it gains in weight, due to the absorption of water.

Steinmetzer (1924) fed pellets prepared from a definite weight of feed mixed with an equal weight of barium sulphate and a little water, the barium sulphate allowing the position of the feed to be photographed by Roentgen rays at any time during passage through the digestive tract. His conclusions are as follows:

> The passage of the food through the gastrointestinal canal of the cock is normally exceedingly rapid; in the case of the food used in our experiments in pill form, in 4 hr. The feed remains in the crop, the gizzard, and the large intestine for equal intervals of time (in our experiments an average of 2 hr.), in the small intestine about half as much longer (in our experiments an average of 3 hr.). The gizzard is without movement when it is in an empty condition, but begins rhythmic movements as soon as food passes to it. The glandular stomach was always found to be empty except for the short moments when from time to time portions of the food passed through it (0.5 to 1 min.). The behavior of the crop was peculiar. Although the attempt was made in all the experiments, no rule could be discovered as to when the pill would fall into the crop and when not.

Mangold (1925) made a careful study of the movement and digestion of starch broth in different parts of the digestive tract of pigeons, from which it was observed that indigestible particles may remain in the gizzard for a long time.

Wide Variability in Rate of Digestion.—Keith, Card and Mitchell (1927) studied the rate of passage of feed through the digestive tract and made the following observations:

Determinations have been made of the amount of dry matter contained in the various segments of the digestive tract of hens at different intervals after the ingestion of 50 g. of whole corn, ground corn, or a mixture of ground corn and tankage in the ratio of 4 to 1.

The results indicate a wide variability in the rate of passage of the food through the hen. In most cases, however, the whole corn had left the crop by the end of 12 to 15 hr. The ground corn remained in the crop distinctly longer than the whole corn and somewhat longer than the mixture of corn and tankage. The amount of dry matter in the other sections of the digestive tract did not differ notably for the three kinds of feed used. The amount of dry matter in the gizzard in addition to the grit was larger while food remained in the crop than later, and to a less extent the same was true of the small intestine. Otherwise the amount of dry matter in the intestines was fairly constant.

The percentage of moisture in the contents of the crop showed a wide variation, apparently independent of the kind of feed eaten and of the time after feeding. The percentage of moisture within the gizzard was low and rather variable, being about 30 to 60 per cent, with an average of 44.2 per cent. The amount was not a reflection of the amount in the crop, but was usually about one and one-half to two times that of the dry matter not grit present. The percentage of moisture within the small intestine was high and remarkably constant at about 82 to 86 per cent, with an average of 83 per cent. That in the caeca was about 70 to 80 per cent of the total contents, with an average of 76.4 per cent; and that in the large intestine was about 75 to 85 per cent, with an average of 78.9 per cent.

The amount of grit found in the gizzard varied widely, the usual range being from 3 to 15 g. No connection was observed between the quantity of grit present and any other factor or condition.

FACTORS AFFECTING DIGESTIBILITY

The coefficients of apparent digestibility of various feeds as given in Table 48 have been determined for the various feeds when fed separately and, for the most part, to normal laying hens and sometimes to males.

Condition of Feed.—When poultry feeds are fed in combination, however, the coefficient of digestibility of the combined product may be affected. Incidentally, according to Kalugin (1897), when fine gravel is mixed with the ration the coefficient of digestibility of the ration is increased, but this observation was not confirmed by Jaeckel (1924) or Katayama (1924). On the other hand, Bartlett (1910) observed that "the equal parts of corn meal and fine cut early clover is sufficiently bulky to feed with concentrates and is more digestible." Bartlett also observed that the mixing of about 7 per cent of bone ash with a ration consisting wholly of vegetable matter gave a somewhat higher average digestion coefficient than when the ration did not contain the bone ash. Halnan (1927–1928) observed differences in the digestibility of different varieties of oats, the varieties with the highest fiber content having a lower digestibility than those with lower fiber contents.

That the condition in which a feed is fed may affect its digestibility is borne out by the observation of Fields and Ford (1900) who found that the digestion coefficients of kafir corn and corn are higher when fed whole than when fed ground. In a general way this observation has been confirmed by K. Krüger (1925) and Mangold (1925).

Nitzescu (1917) observed that well-cured grain has a higher coefficient of digestion than new grain. On the other hand, Halnan (1928*a*), in digestibility trials carried out with White Leghorn cockerels, observed that "weak" and "strong" wheats are equally digestible, the differentiation between the two kinds of wheat being based upon the bakers' classification in England, "strong" wheats being preferable for baking purposes.

Palatability.—Brown (1904) and Bartlett (1910) both observed that the less palatable a feed stuff the lower the digestibility. Although moistening feeds is supposed to increase their palatability, it is interesting to note that Raatz (1926) observed that moistening feeds changed their digestibility. In addition, Mangold (1925) and K. Krüger (1925) observed that the cooking of vegetable feeds lowered their digestibility. Halnan (1928*b*) found that in digestibility trials with whole corn and flaked corn, prepared by steam cooking and subjecting the product to pressure through hot steam rollers, the digestibility of the flaked product was considerably increased.

Although the average coefficients of digestion of the various poultry feeds given in Table 48 represent digestion coefficients obtained from adult laying hens for the most part, it has become apparent that individual birds differ in respect to their ability to digest different nutrients. For instance, Völtz and Yakuwa (1909) and Bartlett (1910) observed differences in the coefficients of digestibility among birds of the same variety. Kaupp and Ivey (1923*a*) observe that digestibility apparently takes place more rapidly in the growing chicken than in the laying hen and apparently more rapidly in the laying hen than in the non-laying hen, and finally more rapidly in non-laying hens than in broody hens. Ackerson, Blish and Mussehl (1928) observed rather wide variations among hens regarding amounts of nitrogen excreted when the hens were on nitrogen-free diets. Molting also affected the amount of nitrogen excreted.

Although there are various factors that affect the digestibility of nutrients, each coefficient of digestibility given in Table 48 must be accepted as representing the average coefficient secured from several digestion experiments carried out with normal birds.

ENDOGENOUS AND EXOGENOUS METABOLISM

According to Bodansky (1927), "the metabolism of tissue constituents proceeds at a rather constant rate, because tissue breakdown in health is usually constant. It may be referred to as endogenous metabolism, in contradistinction to the direct metabolism of foodstuffs, which is called exogenous metabolism." Ackerson, Blish and Mussehl (1928), in an experiment on the endogenous metabolism of hens and capons, observed a striking decrease in the relative amount of nitrogen excreted day by day. Seven Rhode Island Red and eight Barred Plymouth Rock capons showed the same relative decrease in the relative amount of nitrogen excreted as in the case of two Buff Orpington and eight Single-comb White Leghorn hens. These authors also observe that, since Rhode Island hens have been observed to lay eggs 122 hr. after being placed on a nitrogen-free diet, storage of protein occurs in the oviduct for forming the albumen of the egg, or the body is capable of transferring proteins from other tissues for this purpose.

In an experiment on the endogenous nitrogen of hens as affected by molting, Ackerson, Blish and Mussehl (1926) drew the following conclusions: "The average daily loss of endogenous nitrogen was found to be 144 mg. per kg. of body weight in 60 trials with non-molting, mature Rhode Island Red hens. The average daily loss of endogenous nitrogen was found to be 219 mg. per kg. of body weight in 35 trials with Rhode Island Red hens. The variation in the endogenous loss of nitrogen of molting birds from one period to another, precludes their use as subjects in a determination of the biological value of proteins." These results are, in general, confirmation of those obtained by Mitchell (1924*b*). Thompson and Powers (1925) observe that "During the molting season the chicken's metabolism is seriously disturbed, large variations in the uric acid, creatinine and non-protein content of the blood occurring. In general the non-protein nitrogen and creatinine are higher, which indicates a profound disturbance of endogenous metabolism." In another experiment conducted for the purpose of determining the effect of cystine on the endogenous metabolism of molting hens, Ackerson and Blish (1926) found that although in the case of the average endogenous loss of nitrogen of six molting hens, which was 239 mg. per kilogram per day, the addition of 150 mg. of cystine daily to the nitrogen-free ration of six other molting hens produced an endogenous loss of nitrogen of but 137 mg. per kilogram per day.

The influence of castration on metabolism has been studied by Heymans (1921), who found that metabolism was decreased some 20 to 30 per cent under conditions of normal nutrition. The respiratory exchange was lowered, on the average, 15 per cent. The respiratory metabolism of uncastrated males which were fasted was lowered and they lost 50 per cent more weight than capons, showing that the fasted uncastrated males began to utilize proteins while capons utilized the adipose reservoir. Szuman (1926, 1927) secured similar results whereas Pezard (1927) reports that the castration of cockerels at one to two months of age does not influence the respiratory excretions. Reduced metabolism in the case of castrated adult cocks was observed, however, and Pezard suggests that the age for castrating, in order to insure a reduction of metabolism, accompanied as it is by more rapid growth with less feed consumption than in the case of uncastrated males, is from two to three months or later.

CHAPTER XXIII

NUTRIENT REQUIREMENTS

Among the various practices employed in poultry husbandry, probably there is no greater variation than in respect to the rations used, whether in the feeding of growing chicks, market stock, laying hens or breeding stock. There are certain fundamental principles involved, nevertheless, which materially affect results.

The feeds consumed by chickens are used in repairing waste and in providing materials for growth, reproduction, and the storing of fat. The complex character of the body of the chicken and of the egg it lays suggest the nature of the nutrients needed. The body consists of water, minerals, proteins, carbohydrates, fats, and various other organic substances. The egg consists of the albumen, or the white, a secretion of the glands of the oviduct, and the yolk, which is a real cell. The albumen contains approximately 86 per cent water and approximately 12 per cent protein. The other constituents of the albumen are of less importance. The yolk is much more complex than the albumen and contains about 49 per cent water and about 50 per cent solids, which consist of egg oil, protein, carbohydrate, fats, minerals, and other substances. The yolk is also relatively rich in certain vitamins. The shell of the egg consists largely of calcium. The feeds required by chicken must contain these elements in varying quantities and proportions, according to the age of the chicken and the purpose for which it is fed. (Jull and Lee, 1927.)

The composition of the fowl and the egg are given in Table 50, which, however, does not indicate the presence of some of the vitamins. Table 3 and the discussion on pages 3 to 10 contain information concerning the approximate amounts of the various vitamins in the body and in the egg.

TABLE 50.—COMPOSITION OF FOWL AND EGG[1]
(Lippincott, 1927)[2]

	Water, per cent	Protein, per cent	Mineral, per cent	Fat, per cent
Leghorn hen, entire fowl	55.80	21.60	3.80	17.00
Mature Plymouth Rock, capon	41.60	19.40	3.70	33.90
New-laid egg (entire)	65.90	12.83	10.68	10.59
New-laid egg (without shell)	74.45	12.16	0.97	9.74
White of egg	86.20	12.30	0.20	0.60
Yolk	48.63	17.58	1.55	32.23
Dry matter in hen	.....	48.90	8.60	38.50
Dry matter in entire egg	.....	33.30	35.60	25.90
Dry matter in entire egg aside from shell	.....	49.80	3.50	38.60

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[1] The anaylses recorded in this table are from several different sources and are not always in exact agreement.

[2] LIPPINCOTT, WM. A., "Poultry Production." By permission of Lea and Febiger, publishers.

The principal nutrient requirements in the feeding of chickens include water, carbohydrates and fat, proteins, minerals and vitamins.

WATER REQUIREMENTS

Since the body of the fowl consists of over 55 and the egg over 65 per cent water, it is obvious that the need for a liberal supply of water is relatively great. Ten dozen eggs of standard size, two ounces each, contain, approximately one gallon of water. Moreover, since water softens the feed, enables the blood to carry nourishment to the body, aids in the elimination of waste products and serves to keep the body cool by evaporation through the air sacs and lungs, the chicken having no sweat glands, it is one of the most important parts of a chicken's ration. Liberal quantities of water should be supplied at all times.

CARBOHYDRATE AND FAT REQUIREMENTS

The pronounced activity, the very rapid respiration and the high body temperature of the chicken are characteristics demanding a relatively high consumption of carbohydrate and fats. Associated with these characteristics is the well-known law that the smaller the animal the greater is the ratio of body surface and, hence, heat production to live weight. Fats furnish more energy on combustion and are more valuable as heat-producing substances than are the carbohydrates, having a calorific value approximately 2.25 times that of carbohydrates. If the supply of carbohydrates is insufficient, the fats are used to produce energy but, if the supply of carbohydrates is sufficient, the fats are stored in various parts of the body. The fat toleration of birds, however, is not very high because the digestive system is not designed for handling fats in large amounts. Carbohydrates, being more readily handled by the digestive system, are mainly used as a source of heat and energy as well as for the production of fat.

Chief Sources of Carbohydrates.—The chief sources of the carbohydrates for feeding purposes include principally the cereal grains and their products and such other products as potatoes, molasses and sugar. Among the feeds of animal origin, dried skim milk and dried buttermilk are relatively rich in carbohydrates. Among the so-called "green feeds," those relatively rich in carbohydrates are alfalfa and clover hay, alfalfa meal and alfalfa leaf meal.

Chief Sources of Fat.—The chief sources of fats are such feeds as sunflower seed, hempseed, flaxseed, fresh or "green" bone and certain fish and meat meals.

It should be realized, of course, that practically all feeds used in feeding chickens contain varying proportions of carbohydrates and fats, as shown in Table 47. The coefficients of digestibility of the carbohydrates and fats in many of these feeds are given in Table 48. Since the various grains and their products constitute the chief source of the carbohydrates, their relative value in this respect is discussed briefly.

Barley is an excellent poultry feed, though not quite as palatable as corn or wheat. Lomax (1928–1929) found that barley had just as good feeding value as wheat when each was fed as a constituent of the scratch grain. Halpin, Johnson and Hart (1927) report that barley can be substituted for yellow corn in the chick ration if a liberal supply of alfalfa meal is added for the purpose of supplying vitamin A. Hulled barley seems to have no advantage over the whole grain. As far as the use of barley meal is concerned, Jaffa (1905) points out that the grains should be thoroughly ground or the hulls should be sifted from the meal, otherwise they may cause trouble in the chicken's crop.

Buckwheat has a relatively high fiber content and is not very palatable although buckwheat middlings are sometimes used in fattening rations.

Corn is one of the most abundant grains produced in the United States, is readily digested, very palatable, and is, therefore, one of the most valuable poultry feeds. Yellow corn is much more valuable than white corn because it contains vitamin A and xanthophyll, a pigment which produces a rich yellow color in the yolk of the egg. Mitchell (1924*a*), with 8 chickens, secured a biological value of 54 for corn proteins, while Ackerson and Blish (1926*b*), with a group of 43 mature hens, observed that the average utilization of corn proteins was 68 per cent when the ration consisted of whole yellow corn and sugar together with minerals and filter paper for bulk.

Several years ago wheat was regarded as the most important grain for poultry feeding purposes, but as early as 1918 Buss conducted an experiment in feeding laying hens that showed that corn was much superior to wheat in rations containing 81.5 per cent of each. At the same time, Mussehl, Calvin, Halbersleben and Sandstedt (1921) demonstrated that yellow corn is deficient in the quantity and quality of protein required for the normal growth of chicks. Yellow corn also proved to be deficient in minerals.

Yellow and White Corn.—The comparative values of yellow and white corn have been tested by a number of workers. Kempster (1926*c*) found that a ration containing 56 per cent yellow corn was superior to a similar ration containing the same proportion of white corn. The hens which were fed white corn developed nutritional roup after two months and stopped laying, but by changing the ration to yellow corn the trouble was checked. Kempster and Henderson (1926), in an experiment comparing yellow and white corn for growing chicks, with and without eggs as a supplement, found that yellow was superior to white corn without the supplement but the egg yolks corrected the vitamin A deficiencies of white corn. The mortality in the lot receiving white corn was very

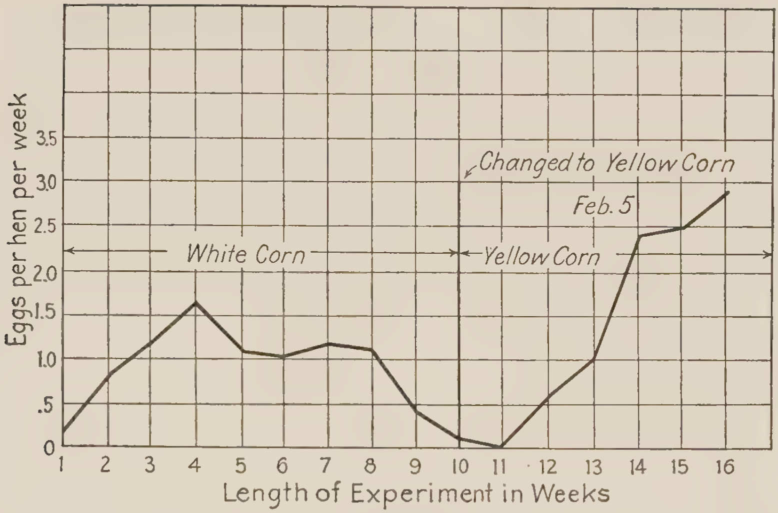

FIG. 146.—The chief difference in the feeding value of white and yellow corn is that yellow corn is rich in vitamin *A*, whereas white corn is very deficient in this vitamin. (*After Kempster*, 1926.)

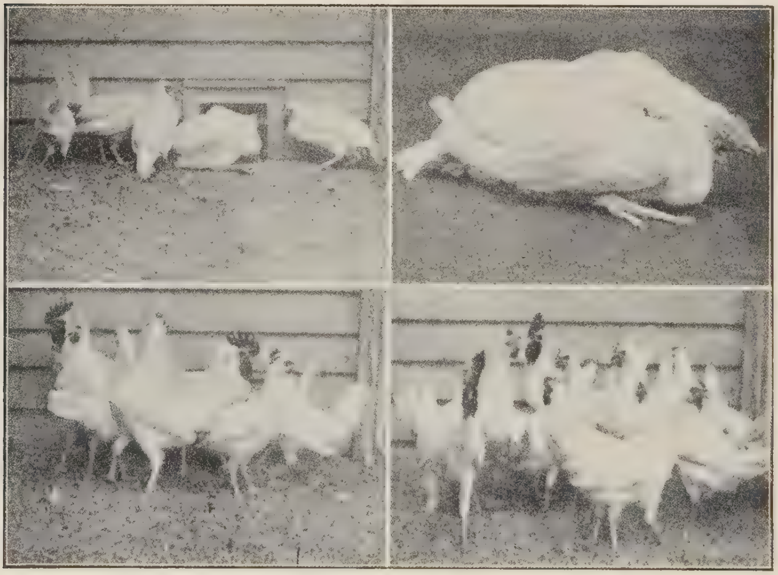

FIG. 147.—Vitamin *A* is necessary for chicks. Upper left, Lot 1, received no yellow corn in their ration. Upper right, individual from Lot 1; note the condition of the eye. Lower left, Lot 2, received 25 per cent yellow corn in the ration. Lower right, Lot 3, received 50 per cent yellow corn in the rations. All chicks photographed at 17 weeks of age. (*Photograph by Hauge, Carrick and Prange*, 1927.)

high. The Indiana Experiment Station (1926) found that in three lots of chicks, one of which received white corn only, another half yellow and half white corn, and another yellow corn only, the lots which received yellow corn only and half each of yellow and white corn grew well up to 20 weeks of age, while the lot receiving white corn only developed opthalmia and all died in about 4 months. Penquite (1925–1926) found that it was impossible to secure good hatches when white corn, either with or without green feed, was fed to the breeding stock.

Corn Products.—There are three other products of the corn crop used as poultry feeds: *corn meal, corn gluten feed* and *hominy. Corn meal* has practically the same feeding value as the whole grain. *Corn gluten feed* is a by-product in the manufacture of glucose and cornstarch. The kernels of corn are soaked and separated into hull, germ, starch and gluten and the gluten is then dried and in that form contains approximately 45 per cent protein and 3 per cent fat. It is mixed with corn bran and sold as gluten feed, but is used only to a limited extent, depending largely on price. *Hominy* is made up of the hull, germ and starch and is a good poultry feed.

Oats are relatively high in fiber as compared with barley, corn and wheat and largely for that reason are used much less in poultry rations. Oats of poor quality frequently contain so much hull as to make them of little use, while oatmeal or rolled oats is a very valuable poultry feed. In barley, corn, wheat and oats, the average percentage of carbohydrates in the form of nitrogen-free extract is, respectively, 66.9, 70.3, 71.1 and 60.7 while the coefficient of digestion of the nitrogen-free extract is, respectively, 82.1, 90.1, 88.9 and 69.3. On the other hand, the percentage of nitrogen-free extract in oatmeal is 66.1 and the coefficient of digestion is 90.5. Oatmeal is a particularly desirable feed for growing chicks and whole oats of good quality are a desirable addition to the laying ration. Hulled oats are also of value in feeding chickens.

Rintoul and Rugg (1922) found that oats gave better results in egg production than wheat, barley and a mixture of 2 parts wheat, 1 part oats and 1 part barley, when each was fed as a night ration. Kennard and Nettleton (1928) found that mixing whole oats at the rate of 10 to 20 per cent by weight in the mash is as desirable as grinding.

Wheat is produced in abundance in some sections of the country and as far as the carbohydrate content is concerned ranks with barley and corn, though it is lower in fat content. It is a desirable poultry feed though it cannot be used as a sole source of feed as demonstrated by the work of Hart, Halpin and Steenbock (1920). The results of Halnan (1928) indicate that soft wheats are equally as valuable for poultry feeding purposes as hard wheats. Moreover, shrunken wheat frequently contains more protein per 100 lb. and, since it is not suitable for milling purposes, it can often be purchased to good advantage for use as a poultry feed.

Wheat Products.—The several by-products of wheat include *wheat bran, wheat middlings, wheat shorts, "red-dog" flour* and *wheat screenings. Wheat bran* consists of the outer layer of the kernel and contains on the average 55.6 per cent nitrogen-free extract, 54.1 per cent of which is digestible. It has some laxative properties but should be used with considerable reserve. *Wheat middlings* contain a higher percentage of carbohydrates and fats than wheat bran and may be used to good advantage in mash rations. *Wheat shorts* are very similar to wheat middlings except that shorts comprise the outer portion of the wheat kernel inside of the outer layer which makes bran. *"Red-dog" flour*, in reality, is a low grade of flour and has apparently the same feeding value as middlings and shorts. *Wheat screenings* are low grades of wheat frequently mixed with foreign material, particularly weed seeds. The feeding value of screenings depends upon their quality.

Rye is relatively rich in carbohydrates and fat, the former of which have a relatively high digestion coefficient but, in spite of all this, rye is not palatable and is not a good poultry feed.

Rice is grown extensively in some sections of the United States and, since it contains a higher proportion of carbohydrates than probably any other feed, it can be used to supplement other grains in the ration. *Rice polish* has a higher digestion coefficient of its nitrogen-free extract than the rough or *unpolished rice*. Katayama (1924) is authority for the statement that rice by-products have a high feeding value. Hoshi and Ukai (1926) observe that a diet of polished milled rice gave rise to certain changes in the pancreas. Hoh and Kam (1926) secured fairly good results in fattening chickens with a ration of 2 parts of rice bran and 1 part of cooked polished rice and another ration of 4 parts of rice bran, 2 parts of cooked polished rice and 1 part of peanut cake. Experiments conducted at the Arkansas Agricultural Experiment Station (1927) failed to demonstrate the value of rice in any combination with a normal ration in feeding for egg production.

Other Grains.—*Emmer, feterita, dura, shallu, millet* and *milo*, produced in local sections of the country, are suitable feeds under certain circumstances. *Kafir* is quite a valuable feed, Lippincott (1927) being authority for the statement that at the Kansas Agricultural Experiment Station kafir has given only slightly less satisfactory results than corn, when used as the principal grain. *Milo* is similar to kafir but apparently does not have quite as high a feeding value.

Summary of the Feeding Value of Grains.—Grains primarily supply carbohydrates, but at the same time also provide some of all other nutrients. Apart from the slight vitamin A content of yellow corn, there is, as pointed out, little qualitative difference between the different grains with regard to vitamins. Therefore their total digestible nutrients give a fair expression of their relative feeding value. Comparing the digestible nutrients and not considering the value of variety, it is seen that corn is slightly higher in feeding value than wheat and that they are both worth about 15 per cent more than barley or oats.

In feeding grain, as well as any other feed, these comparative figures should always be borne in mind and serve as a fundamental basis in composing the ration. (Holst and Newlon, 1927.)

Miscellaneous Feeds.—Other feeds relatively rich in carbohydrates include *potatoes, molasses, sugar, dried skim milk, dried buttermilk* and some of the "green feeds."

A few experiments conducted with *potatoes* in the ration, Kennard (1929), Elford (1927), go to show that cheap potatoes may be used to some extent as a supplement to the mash ration in feeding laying hens and in fattening chickens for market. Some work has been done to determine the value of *molasses* in feeding poultry but its place in the feeding of chickens has not been well established. Lippincott (1927) reports that adding sufficient molasses to a basal ration of oat flour to form 10 per cent of the solid portion of a milk-fattening ration the average gains in weight were slightly increased on a lower feed consumption. *Sugar*, of course, is composed entirely of carbohydrates, although Hartwell and Kirkpatrick (1911) found that the addition of sugar to broiler-fattening rations did not improve the results secured. While it is true that *dried skim milk* and *dried buttermilk*, as well as some of the "green feeds," contain considerable amounts of carbohydrates, these feeds are fed to chickens primarily for other purposes and a discussion of the particular purpose they serve is given in appropriate sections.

PROTEIN REQUIREMENTS

The most prominent component of the body of the fowl, aside from water, is protein. The basis of muscular and glandular tissue is protein. Moreover, the egg contains a higher percentage of protein than the majority of the cereal grains. Then, again, the fact should be kept in mind that a portion of the protein of the cereal grains remains undigested when fed to chickens.

Amino-acids Differ in Feed Value.—Protein is composed of amino-acids, about 20 of which are known. Zein is the protein of corn, but zein is deficient in certain amino-acids that are regarded as essential for most efficient growth. Certain of the amino-acids are more important than others. Also, some of them, such as glycocoll, can be formed in the body of the chicken from the excess of other amino-acids present, whereas, others, such as cystine, lysine and tryptophane, can only be formed in the body of the chicken from the amino-acids supplied in the feed. It has been determined in nutritional work with other animals that some of the amino-acids can replace each other while others cannot. Presumably the same thing applies in poultry nutrition. In feeding practice, therefore, the source and kind of protein is an important matter. In Table 51 are given some of the more common proteins fed to chickens together with some of the amino-acids they contain.

While it is true that the nutritive value of proteins depends upon their yield of the indispensible amino-acids, very little work has been done to determine the value of the different amino-acids. Buckner, Nollau and Kastle (1916) secured results in two lots of chicks which seemed to show that an amino-acid called "lysine" was responsible for the better growth secured in one of the lots. Ackerson and Blish (1926*a*), in an experiment on the endogenous metabolism of molting hens, observed that a sulphur-containing amino-acid called "cystine" exerted a protein-sparing effect out of proportion to its nitrogen content. Most of the other work on the determination of the value of proteins has not been with respect to the kind of amino-acids they contain but more from the standpoint of the kinds of feed supplying the proteins.

TABLE 51.—PER CENT OF TOTAL NITROGEN IN THE FORM OF AMINO-ACIDS IN VARIOUS PROTEINS

(Mitchell and Hamilton, 1929)

Source of protein	Per cent of total nitrogen					
	Arginine	Cystine	Tyrosine	Histidine	Lysine	Tryptophan
Zein (corn)	3.6	0.5–0.6	2.7–2.8	1.3–2.1	0.0	0.0–0.14
Gliadin (wheat)	4.7	1.6	1.3	4.3	1.6	0.6–0.8
Avenalin (oat)	15.0	1.0	....	8.3	3.5	0.9
Hordein (barley)	5.4	1.0	....	1.6–3.6	1.0	0.6–0.8
Casein (milk)	7.4	0.2	2.7	6.2	10.3	1.9
Myosin from muscle (hen)	17.3	1.6	....	6.7	9.0	
Myogen from muscle (hen)	18.1	1.2	....	6.6	10.1	
Yolk (hen egg)	14.5	....	....	3.1	9.4	1.1–1.5
White (hen egg)	11.7	....	2.0	0.2–4.0	10.1	1.1–1.2

It is easy to understand, therefore, that protein is not only one of the most important of all of the requirements, in the feeding of poultry, but also that the source of the proteins is an important matter.

Excessive Protein Harmful.—There is another aspect of the problem of protein requirements which greatly affects feeding principles.

If protein is provided in excess of requirements, the amino acids are formed and absorbed by the blood as usual. In the liver, however, they are deprived of their nitrogen, thus being transformed into one or both of two other classes of nutrients, carbohydrates and fats. The fate of the tissue protein after it is worn out is similar. It is broken down into amino acids, which are then deprived of their nitrogen, the remaining part being used in the animal organism. The nitrogen thus separated from the amino acids does not appear in the free form, but is normally split off as ammonia, which is transformed inside the bird's liver into uric acid and urea, substances which are then expelled as parts of the urine through the kidneys. A diet too high in protein, therefore, puts an unnecessary and dangerous burden on these organs. (Holst and Newlon, 1927).

Protein Requirements Determined by Age of Birds.—It has been determined that the protein requirements of chickens depend upon whether chickens are being fed for growth, egg production or for fattening. From the work of Soxhlet (1878), Bunge (1905), Ellenberger and Schuenert (1925)and others, it has been determined that there is a close relationship between the rate of growth of different animals and the protein content of their ration. Malarski (1920) found that the yolk remaining in an egg after 20 days of incubation contained 1.6 parts of protein to 1.74 parts of fats and lecithins and observed that rations containing approximately the same proportion of protein gave good results. Holst (1927) observes that the nutritive ratio of the absorbed egg yolk during the first two days after hatching is 1:1.4 and suggests that the chick ration for the first few weeks should be relatively high in protein. Mussehl and Gish (1925) and Mussehl (1926) have shown that during the first nine weeks chickens can tolerate and even make good use of animal protein concentrates to the extent of approximately 20 per cent of the total ration when added to a basic ration of corn, wheat and barley, plus minerals. Raatz (1925) observed a correlation between the protein content of the ration and the rate of growth. Hart, Halpin and McCollum (1917) found that a protein level of approximately 12 per cent in laying rations did not produce good egg production. Hansson (1928) observes that the protein requirements of laying hens increase as egg production increases.

Sources of Protein.—The protein requirements of both growing chicks and laying hens have been investigated by a large number of workers over a period of years. Since the grains which are fed primarily as a source of carbohydrate supply do not contain sufficient protein or are deficient in certain aminoacids, as in the case of the proteins of corn, it must be supplied from feeds that are relatively rich in protein. Among plant products, those which have been used principally as a source of protein supply include cottonseed meal, soy bean meal, linseed oil meal, peanut meal, cocoanut meal and cowpeas. The principal animal products rich in protein include dried and fresh blood, fish meal, fresh meat, meat and bone scraps, tankage and milk. Investigational work has been confined for the most part to cottonseed meal, soy-bean meal, meat and bone scraps, tankage and milk.

Cottonseed meal is a feed produced in great abundance in cotton-growing sections and, since it is cheap and relatively rich in proteins, approximately 76 per cent of which are digestible, it has been used extensively in the feeding of poultry in the cotton-producing areas. Considerable work has been done to determine the value of its proteins as a source of supplements to the cereal grains. Jeffrey (1910) found that mash containing cottonseed meal was not relished and that egg production was lower than when meat meal was used as a source of protein supplements. On the other hand, Morrison (1913) found cottonseed meal to be quite palatable and that the birds remained in as good condition in a six-months' feeding trial as those receiving beef scraps, and egg production was a little higher, although it should be observed that twice as much cottonseed meal was used as beef scraps. Hartwell and Lechtenthaeler (1914) fed different lots of chicks equal levels of nitrogen from cottonseed meal and beef scraps and found that, if the constituents of bone are supplied, moderate growth is made on cottonseed meal but best growth is obtained by using beef scraps, regardless of the amount of feed consumed.

Gossypol.—The coloring matter of the kernel of the cottonseed contains gossypol, a compound believed to possess poisonous properties. Since cottonseed meal contains approximately 0.8 per cent of crude gossypol, it is readily understood why care must be exercised with respect to the amount of cottonseed meal used in the ration. Kaupp (1915*b*) found that a mash containing 10 per cent cottonseed meal was palatable and the birds showed no ill effect, while a mash containing 20 per cent proved unpalatable and the birds showed a tendency to become sick.

Cottonseed Meal versus Animal Products.—Ahrens (1917) compared cottonseed meal with beef scrap and found that, although from the standpoint of hatchability cottonseed meal was superior to beef scrap, from the standpoint of egg production the reverse was true. The mortality among chicks was, moreover, considerably higher from the pen receiving cottonseed meal. Philips (1919*b*) secured an average egg production of 55.69 eggs per bird from pullets fed cottonseed meal as compared with an average of 166.87 eggs per bird from pullets fed 50 lb. of buttermilk in place of 5.3 lb. of cottonseed meal in the ration.

Sherwood (1924) conducted tests comparing the value of cottonseed meal with various animal products rich in protein and found that freshly ground cottonseed meal could replace a considerable portion of the meat scrap, tankage, or fish meal and give practically as good results as when each of these animal products was used. Kennard and White (1924) tested the value of mineral supplements to a mash containing 20 per cent cottonseed meal as compared with a mash containing 20 per cent cottonseed meal without the minerals and secured a striking difference in egg production. They observe that "although the addition of minerals more than doubled the value of the cottonseed meal ration for egg production, it only reached 85 per cent the value of the meat-scraps ration. From these results it would seem that cottonseed meal can not be successfully used to replace meat scraps in the ration for layers. This does not mean that a partial replacement could not be made to advantage." Kempster (1924), however, observes that cottonseed meal in combination with meat scrap or tankage does not increase egg production.

The extensive series of experiments in determining the relative value of cottonseed meal as compared with animal products carried out by Kempster and Henderson (1922, 1925) seem to show that when meat scraps or tankage are used, cottonseed meal should not be used in excess of approximately 5 per cent of the ration. R. B. Thompson (1925–1926) fed rations containing varying amounts of raw and processed cottonseed meal and secured practically uniform results in egg production but minerals added to all of the rations increased production and decreased the cost of feed per dozen eggs.

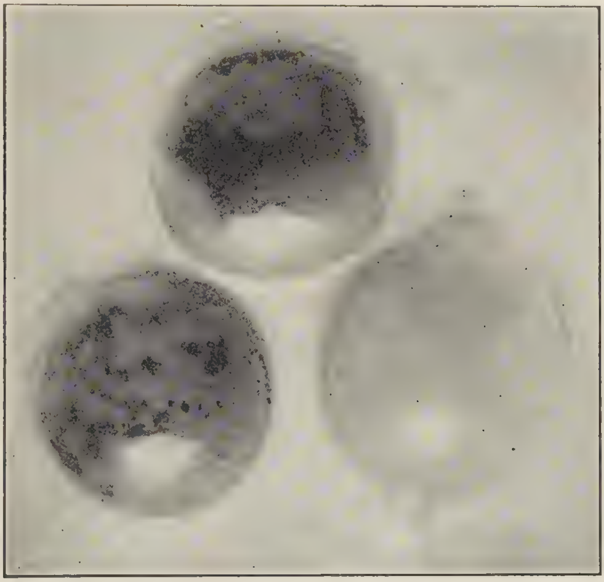

FIG. 148.—The two yolks showing the black spots were produced on a ration rich in cottonseed meal, whereas the other yolk was produced by a hen fed on a ration with only 10 per cent of cottonseed meal in the ration. (*Photograph by U. S. Dept. Agr.*)

Cottonseed Meal and Yolk Color.—Berry (1927) found that a mash ration containing 38 per cent cottonseed meal, with birds on an alfalfa range, led to the production of eggs with dark spots on the yolks. Bethke and four coworkers (1928) found that the proteins of cottonseed meal were superior to those of linseed meal for growing chicks. The results indicated that the age of a chicken influences its response to cottonseed meal or linseed meal feeding. Sherwood (1928) studied the influence of feeding cottonseed meal of prime quality and containing 43 per cent protein on the quality of eggs produced, and concluded that not over 9 per cent in the total ration and not over 6 per cent in the "all-mash ration" should be used. While none of the eggs showed any serious discoloration of the yolk or white when first laid, higher percentages of cottonseed meal than those mentioned above produced a distinct discoloration after the eggs were held in cold storage for only four weeks.

Cottonseed meals from different sources and produced by different processes of manufacture seem to vary greatly in their toxicity and feeding value.

Linseed oil meal is obtained from flaxseed after the extraction of the linseed oil. "Old process" linseed oil meal, designated O.P. is the residue of the flaxseed left when the oil has been expressed by hydraulic pressure. "New process" linseed oil meal, designated N.P., is the residue left after the oil has been dissolved out of the crushed and heated flaxseed by the use of naptha. The new process meal, therefore, contains less fat than the old process meal, though both are relatively rich in protein.

Kempster (1924) found that linseed oil meal, when comprising as much as 25 per cent of the mash, produced no better results in egg production than when no protein supplement of any kind was used.

Soy-bean meal, or soy-bean oil cake meal, and soy-bean oil meal are obtained from the manufacture of soy-bean oil and are relatively rich in proteins, which have a relatively high coefficient of digestibility (see Table 48).

Dougherty (1918) found that soy-bean meal could be used to good advantage. Results secured at the Indiana Experiment Station (1923) indicate that soy-bean oil meal when supplemented with minerals, can replace tankage in rations for egg production. Kennard and White (1922) and Kennard, Holder and White (1922) secured results that confirm those mentioned above, when 1 part of soy-bean meal was added to a mash ration consisting of 2 parts corn meal, 1 part ground oats and 1 part standard wheat middlings, plus a mineral mixture, and in addition a scratch ration of 3 parts corn, 1 part wheat and 1 part oats. Philips and Hauge (1925) found that soy-bean oil meal was a satisfactory source of concentrated protein in a laying mash when supplemented by a mineral mixture consisting of 24 parts limestone and 15 parts salt with either 21 parts soluble bone, 22 parts steamed bone or 42 parts acid phosphate. Van der Plank (1927) reports that a ration of 20 parts corn meal to 10 parts soy-bean meal, supplemented with 1.5 parts of dried buttermilk, gave a positive nitrogen balance in digestion and produced excellent results. Card (1928) found that 20 parts of soy-bean meal supplemented with 4 per cent of steamed bone meal and 1 per cent salt, to supply minerals, could replace 20 parts of meat and bone scraps in the ration of young chicks.

Peanut meal is a by-product in the manufacture of peanut oil. Results secured by Kennard and White (1922) indicate that it may be used as a protein supplement for egg production or growth when proper minerals are fed in addition. Ivey (1927) fed peanut meal in comparison with cottonseed meal, soy-bean meal and meat meal and secured 117.75 eggs per bird from the peanut meal as compared with 137.00, 128.60, and 113.1 eggs per bird, respectively.

Cocoanut meal is a by-product in the manufacture of cocoanut oil and is relatively rich in protein though practically no work has been done to determine its value as a poultry feed.

Cowpeas are not only rich in protein but contain some of the essential amino-acids lacking in the cereal grains. Parkhurst, reported by Philips and Hauge (1925), secured much poorer results from pea meal, supplemented with a commercial mineral mixture, than from meat scraps and skim milk. Parkhurst (1924) observed that when pea meal was fed as the only protein supplement, no better results were secured than when no protein supplement was used, but when pea meal and sour skim milk were used very satisfactory egg production was secured.

Vegetable Proteins Deficient.—From what has been said of the relative value of the various plant products as sources of protein it is apparent that practically all of them require to be supplemented with mineral mixtures of one kind or another. Sufficient evidence has been submitted, moreover, to show that for the most part vegetable proteins are not as valuable as animal proteins in feeding for growth or for egg production. Animal products, therefore, have a particular place in the feeding of poultry and their protein value has a direct bearing on feeding principles. The great question of practical importance is the price of protein-rich feeds of plant origin as compared with those of animal origin. The protein supplements are, in a large measure, by-products in the manufacture of products for human use and, as long as there is a large livestock industry, by-products of animal origin should be readily available at reasonable prices.

Blood, either fresh or dried, is not used extensively in feeding poultry. Fresh blood is sometimes used in wet mashes. Dried blood does not seem to be palatable, as observed by W. P. Wheeler (1907), and apparently should be used to a limited extent only, if at all.

Fish meal and fish scrap are by-products of the fishing industry. Bartlett (1917) gives the chemical composition of fish wastes from sardine factories, and Rosedale (1928) discusses the proteins of fish. Le Clerc (1928) describes two kinds of fish meal; white fish meal produced principally from the waste of edible fish such as the cod, halibut and haddock or from the whole fish, and oily fish meal produced usually from the whole body of the herring, menhaden, pilchard, sardines and mackerel. Also, salmon meal is made from the offal of the salmon. Fish scraps, on the other hand, usually contain a larger percentage of the heads, tails and scales of fish than fish meal and are used largely as a fertilizer.

Kaupp and Dearstyne (1923) found that fish meal may be used to replace meat meal for egg production, fattening or rearing and no fishy flavor was imparted to the eggs or flesh when given in quantities up to 20 per cent. Elford (1924) found that a mash containing 20 per cent fish meal gave practically the same results in egg production as other mashes containing each 20 per cent beef scrap and tankage. Sherwood (1924) observed that fish meal is a good substitute for tankage. Roemer (1927) found that fish meal, meat meal and dried buttermilk were of equal value in the production of eggs when each was added to a basal ration of 40 per cent wheat middlings, 15 per cent each of corn and crushed barley and 10 per cent of oat flakes. Fish meal may have one advantage over such products as meat and bone scraps and tankage, because it contains iodine.

Fish scrap was found, by Philips (1915), to give practically as good results in egg production as meat scrap and skim milk and, by Dougherty (1914–1915) to be as good as meat scrap for egg production.

Fresh meat is used occasionally when old horses or other animals are slaughtered locally and is a valuable protein supplement and although it is palatable it must be fed carefully especially in hot weather.

Meat and bone scraps are defined by the Association of Feed Control Officials of the United States as "the ground dry-rendered residue from animal tissues exclusive of hoof, horn, manure and stomach contents, except in such traces as might occur unavoidably in good factory practice. When this product contains more bone than that amount equivalent to 22 per cent of tri-calcium phosphate, it shall be designated Meat and Bone Scraps. If they bear a name descriptive of their kind, composition or origin they must correspond thereto."

Meat and bone scraps differ from tankage in that meat and bone scraps are made only from the dry-rendered residues to which no blood or "stick" has been added. The "stick" is a dark brown, thick liquid obtained from the wet process of rendering the waste products of the packing industry. Tankage may be made from the wet-rendered or dry-rendered residue or a mixture of the products from both processes to which may be added blood and the "stick." Meat and bone scraps, therefore, are regarded as a higher grade product for poultry feeding purposes.

Meat Scraps Preparation.—Clemen (1927) gives an excellent account of the manner in which the various by-products of the packing industry are prepared for disposal. Because of the great variation in the kinds of products that are made into meat and bone scraps, it is natural to expect considerable variability in respect to the nutritive value of different samples. Hoagland and Snider (1926*a*, 1926*b*, 1927) have shown that the protein of different organs and tissues of animals have different nutritive values. Kraybill (1928) urges caution in respect to the selection of meat and bone scraps for feeding purposes. "If the meat scrap is made up almost entirely of the cracklings resulting from the rendering of adipose tissues, the proteins of which consist mainly of gelatine, it would not have the same nutritive value as if it were made largely of flesh. In studying the relative nutritive value of these animal by-product feeds, it is important to give careful consideration to the products from which they are derived."

Meat Scraps in Laying Rations.—Because of the relatively high value of meat and bone scraps in the feeding of poultry a great deal of investigational work has been carried on to determine the proper amounts to use with respect to the rest of the ration. It will be impossible to give more than a passing reference to some of the investigations. Moreover, the results secured by many of the different workers are in the main similar, so that a detailed discussion of all of the results is unnecessary. Those especially interested in this aspect of the feeding problem may consult the references for further details.

Lewis (1913) observes that "the addition of animal protein in the form of meat scrap materially increases the efficiency of a ration relatively high in vegetable protein, both for egg production and for flesh growth." Philips (1915, 1918*b*, 1919*c*, 1921) conducted an extensive series of experiments over a period of years and secured uniform results from the standpoint of determining the value of meat scraps as a supplement to the laying ration. From the standpoint of egg production per bird the following results were secured: in 1918 the check pen produced 61.2 eggs and the meat-scraps pen 135.9 eggs; in 1919 the check pen produced 59.35 eggs and the meat-scraps pen 179.0 eggs; in 1921 the check pen produced 45.8 eggs, the 5 per cent meat scraps pen 107.6 eggs, the 10 per cent meat-scraps pen 112.1 eggs, the 15 per cent meat-scraps pen 123.1 eggs and the 20 per cent meat-scraps pen 130.0 eggs.

Kempster (1924), compiling the averages of several years' comparisons of mashes containing 5, 10, 15, 20, 25 and 34 per cent of meat scraps, found that maximum egg production was obtained with mashes containing 25 or 34 per cent, though mashes containing 20, 15, 10 and 5 per cent were calculated as 96.3, 94.5, 93.9 and 89.9 per cent, respectively, as efficient. The check mash containing no animal protein was only 55.9 per cent as efficient. Kempster recommends mashes containing from 15 to 25 per cent of meat scraps for practical use. Sherwood (1924) found that adding 100 parts of meat scraps to a mash consisting of 125 parts of wheat bran, 75 parts of wheat shorts and 100 parts of milo meal gave better results in egg production than various combinations of meat scraps and cottonseed meal and tankage and cottonseed meal.

Meat Scraps in Chick Rations.—In a study of the protein requirements of growing chicks, Mussehl and Gish (1925) conclude that chicks make good use of meat and bone meal, when added to a basic ration of corn, wheat and barley plus minerals, to the extent of 19.5 per cent of the total ration, while the growth rate is progressively improved as the amount of the meat and bone meal is increased. Martin (1925) observes that a mash containing 20 per cent meat scraps will yield more eggs and more profit than one containing up to 15 per cent meat scraps. On mashes containing 5, 10, 15 and 20 per cent meat scraps, respectively, he secured the following average egg production per bird: 108.7, 125.5, 133.3 and 145.5.

Prange, Hauge and Carrick (1927), and Prange, Carrick and Hauge (1928*a*, 1928*b*) found that certain kinds of meat meal did not give satisfactory growth in chicks, from which it is concluded that certain amino-acids may have been deficient. Moreover, "meat scraps from various manufacturers did not give the same rate of growth when fed at the same protein level with mineral variations equalized." The suggestion is made that the particular kind of basal ration used has a direct bearing on the results secured from meat meal and meat scraps when used as protein supplements. Massengale (1929) tested the value of a meat-scraps product made from trimmings and refuse collected from local butcher shops and containing 48.5 per cent protein and found that a ration containing approximately 12 per cent of meat scraps gave better results than when 15 per cent or 17.5 per cent was used.

Tankage, the definition of which as adopted by The Association of Feed Control Officials of the United States, is . . .

> The residue from animal tissues exclusive of hoof, horn, manure and stomach contents, except in such traces as might occur unavoidably in good factory practice, especially prepared for feeding purposes by tanking under live steam or by rendering or a mixture of the products made suitable by drying and grinding. When these products contain more bone than the amount equivalent to 22.0 per cent tri-calcium phosphate, they shall be designated Digester Tankage with Bone, Meat and Bone Meal Digester Tankage, Meat and Bone Meal Tankage, or Feeding Tankage with Bone. If they bear a name descriptive of their kind, composition or origin, they must correspond thereto.

Tankage in Laying Rations.—Investigational work to determine the relative value of tankage as a protein supplement has shown that, for the most part, tankage is of equal value to meat and bone scraps. There are exceptions, however, apparently depending largely upon the quality of tankage used. Philips (1919*b*) compared commercial "digester" tankage with commercial meat scraps and secured 183.5 eggs and 179.0 eggs, respectively, as against 59.35 eggs for the pen which received neither tankage nor meat scraps. The Iowa Agricultural Experiment Station

(1923) found that a basal ration of scratch grain, 2 parts whole corn and 1 part oats and a mash of equal parts ground corn, ground oats and flour middlings produced 43.2 eggs per bird, while the same ration plus 20 per cent tankage produced 117.5 eggs per bird and the same ration plus 20 per cent meat scraps produced 98.4 eggs per bird. Parkhurst (1924) compared tankage and meat meal for three years and found that although the use of meat meal gave slightly better production, the use of tankage gave greater profits over feed costs and a cheaper feed cost per dozen eggs produced.

Kempster (1924) secured practically the same results with tankage as those reported previously for meat and bone scraps. Sherwood (1924) found that "tankage gave as satisfactory results as meat scraps when fed in the proportion of 83 lb. tankage to 100 lb. meat scraps." Philips and Hauge (1925) found tankage to be a satisfactory source of animal protein in a laying mash, needing no additional minerals.

Tankage in Chick Rations.—Prange, Hauge and Carrick (1928) used two different brands of digester tankage in chick rations, the percentages of tankage of the total ration in one case being 8.41, 16.83 and 25.25, respectively, and in the other case 8.60, 17.20 and 25.80, respectively. The general conclusion was that both kinds of tankage used produced very slow growth.

With the exception of the results secured by Prange, Hauge and Carrick, it would appear that tankage is practically as valuable as meat and bone scraps as source of protein supplement, at least in feeding for egg production.

Milk provides a number of products which are of great value in the feeding of chickens of all ages and for all purposes. The principal milk products used in poultry feeding include *liquid skim milk, dried skim milk, liquid buttermilk, condensed buttermilk, dried buttermilk* and *whey.*

The various milk products contain proteins that are easily digested and of considerable value. Moreover, they also contain certain minerals essential for proper growth and most efficient egg production and a valuable carbohydrate called "lactose." Hamilton and Card (1924) observe that lactose is utilized fairly completely by chickens, the quantity present in milk products normally consumed being completely absorbed.

Milk also contains lactic acid, and Hunziker (1923) suggests "that in the case of condensed buttermilk, the real value of the product as a feed is materially augmented by its very high content of acid, calculated as lactic acid." On the other hand, Carrick (1925) observes that:

> Carefully controlled experiments have not shown this to be true in feeding chickens under normal conditions. The available evidence indicates that lactose is responsible for the benefits ordinarily and erroneously assigned to the lactic acid. Lactose favors the development of acid-producing bacteria in the intestine

and through the multiplication of these "friendly germs" the objectionable putrefactive bacteria are suppressed, thus providing good intestinal hygiene. Milk proteins being consumed with lactose are somewhat protected from putrefaction in the intestine.

Milk products contain some vitamin B but very small amounts, if any, of the other vitamins although Norris, Heuser and Wilgus (1929–1930) suggest that milk contains a hitherto unrecognized vitamin which is essential for the prevention of a peculiar type of paralysis involving the legs and feet. It is also suggested that the new vitamin is growth promoting in character. A factor of importance, however, is that milk products appear to add palatability to the rations, thus giving rise to an increased consumption of feed, which in turn tends to stimulate growth and increase egg production.

The Preparation of Milk Products.—For the most part, condensed buttermilk is manufactured by evaporation in a vacuum pan. Dried skim milk and dried buttermilk are manufactured by both the spray and the roller process. In the spray process the product is first condensed in a vacuum pan and is then atomized and dried in a current of hot air. In the roller process the product is kept in a thoroughly agitated condition and is sprayed on a revolving roller, which is steam heated so that the product is heated to a temperature of about 190 to 200° F. The thin film of dried product that forms on the roller is removed automatically by a sharp knife.

Liquid skim milk and liquid buttermilk each contain approximately 9 per cent solids and 90 per cent water. Condensed buttermilk usually contains approximately 25 to 33 per cent total solids and from about 67 to 75 per cent water, although there is considerable variation in ratio of concentration among different lots prepared by different manufacturers. Dried skim milk and dried buttermilk usually contain approximately 90 per cent solids and about 10 per cent water. On the basis of total solids per pound, the dried products have approximately three times the food value of the condensed products, and the condensed products have approximately three times the value of the fluid products.

Milk in the Chick Ration.—Numerous experiments have been conducted to determine the value of the different milk products in feeding chickens and milk products have been compared with other animal products as sources of protein supplements. W. B. Anderson (1898) observed that when skim milk was added to the ration, feed consumption increased. Nixon (1913) obtained better growth by moistening the mash with sour skim milk. Rettger, Kirkpatrick and Card (1915) made a study of the value of milk when fed to growing chicks and compared sweet and sour liquid milk. From their studies they drew the following conclusions:

The feeding of milk to young chicks has a most favorable influence on the growth and on the lessening of mortality of the chicks. It tends to prevent mortality from all causes, and if fed soon enough and for a sufficient long period, greatly reduces the death rate caused by bacillary white diarrhea. Sweet and sour milk are apparently of equal value in their relation to growth and mortality. Furthermore, different degrees of souring do not alter the results of milk feeding. The value of milk as a food for chicks does not depend upon any acids that may be present, nor upon any particular types of microorganisms; but upon one or more of the natural constituents of the milk.

Milk in the Laying Ration.—Philips (1915, 1918*b*, 1919*b*, 1921) conducted quite a number of tests to determine the relative value of milk products as sources of protein supplement for egg production and his results covering several years' work are summarized briefly. In one series of experiments the average egg production per bird with sour skim milk was 135.4 eggs, with meat scraps 135.0 eggs, with fish scraps 128.0 eggs, and the check pen laid only 32.5 eggs; the consumption of feed per bird was 63.86 lb. in the milk-fed pen, not counting the milk solids, or 70.14 lb. including the milk solids, 70.29 lb. in the meat-scraps pen, 74.13 lb. in the fish-scraps pen and 57.01 in the check pen. In another series of experiments the results were as follows: skim milk 140.2 eggs, meat scraps 135.9 and check pen 61.2 eggs; the average amount of dry matter required to produce one dozen eggs was 4.90 lb. in the case of skim milk, 5.14 lb. in the case of meat scraps and 9.57 lb. in the case of the check pen. During the second year skim milk was added to the ration of the first-year check pen with the result that the birds laid more eggs during the winter months of the second year than they did in the same period as pullets. Another series of experiments produced the following results: liquid buttermilk 164.7 eggs, dried buttermilk 189.4 eggs and no milk 56.6 eggs per bird; the amount of feed required to produce one dozen eggs was 3.56 lb. in the case of liquid buttermilk, 3.22 lb. in the case of dried buttermilk and 8.61 lb. in the no-milk pen.

An experiment of considerable interest was conducted by Atwood (1923), the results given here being part of an abstract appearing in the *Experiment Station Record*, vol. 50, No. 1, pp. 71–72:

> The chicks used for the study were pedigreed and all but full sisters were removed at 20 weeks of age. Both lots had received the same grains and cabbage or sprouted oats from hatching time, but one lot (A) received a liberal supply of skim milk, whereas in the other lot (B) the amount was limited. After the first egg was laid the sisters were placed together and received like care and feed. Trap nest records of their egg production were kept, as well as records of the average weekly feed consumption and weights of the chicks, age of laying first egg by each of the 27 pullets on the liberal skim milk ration and the 28 pullets on the limited skim milk ration, individual monthly weights of the pullets, and average monthly egg production and egg weights. Similar data were pre-

sented for these birds during their second year and for the first year's production of their daughters raised on the rations which their dams received. The lot receiving the limited amount of skim milk ate less grain and gained so slowly that the amount of skim milk was increased after 15 weeks of feeding. Some of the more interesting data reported for each group are given in the following table:

TABLE 52.—EFFECT OF LIBERAL AND LIMITED FEEDING OF SKIM MILK TO GROWING CHICKS ON THE ADULT FEMALES

(Atwood, 1923)

Lot	Weight per 100 chicks at 13 weeks of age, pounds	Dead chicks 2 to 17 weeks, number	Averages for pullet year			Average for second year		Average for pullet year of daughters		
			Age at first laying, days	Weight on Jan. 22, 1921, pounds	Eggs produced to Dec. 1, 1921	Av. weights for Oct., Nov. and Dec. 1922, pounds	Egg production	Age at first laying, days	Weight on Dec. 1, pounds	Egg production
A[1]	151.4	18	179.0±1.9	2.97	149.3±4.2	3.53±0.05	151.22±3.9	197.8±3.7	3.58	141.54±6.1
B[2]	52.0	34	199.4±3.8	2.07	115.6±4.8	3.28±0.04	148.41±2.4	228.5±1.7	3.26	120.83±3.4

[1] Lot A received liberal supplies of skim milk.
[2] Lot B received limited supplies of skim milk.

A liberal supply of liquid skim milk as compared with a limited supply induced faster growth, produced a lower mortality, a higher egg production for both the first- and second-year although the difference was not significant in the second year. The daughters hatched from the pullets that received the liberal supply of skim milk produced approximately 20 more eggs per bird than the daughters hatched from the pullets that received the limited supply of skim milk although the difference was not significant.

Kennard, Holder and White (1923) fed approximately 10 per cent of liquid buttermilk as a supplement to corn meal, the latter being deficient in minerals and containing some proteins that are deficient. It was found that the 10 per cent of liquid buttermilk contained sufficient inorganic salts to supply the mineral deficiency of the corn meal. The Iowa Experiment Station (1923) secured an average egg production per bird of 119.8 eggs per bird when the basal ration contained 15 per cent dried buttermilk, 145.1 eggs per bird when fresh buttermilk was given as a drink instead of water, and 43.2 eggs per bird in the check pen, the basal ration for all pens consisting of scratch grain, 2 parts whole corn and 1 part oats and a mash of equal parts ground corn, ground oats and flour middlings. In 1924 the same station fed the following amounts of milk products per pound of mash: skim milk 4, liquid buttermilk 4.5, condensed buttermilk 1.25, and dried buttermilk 0.25 and secured an average production per bird of 146, 126, 143 and 129, respectively, as compared with 41 for the check pen.

Parkhurst (1924) found that sour skim milk gave practically as good results as pea meal and sour skim milk and that whey gave only slightly better results than the check pen. Kempster and Henderson (1925) secured an average egg production per bird of 112 eggs with a ration containing 35 per cent of dried buttermilk, 125 eggs when the birds were given sour skim milk, and 61 eggs with the check pen. Rugg and Pederick (1925*a*) compared 10 per cent of dried milk with 10 per cent of meat meal as supplements to the laying ration and observed that the pen receiving the dried milk consumed 430 lb. more mash than the other pen and that egg production per bird was 211 as compared with 175, the extra feed cost in the milk-fed pen being more than offset by the increased egg production.

Milk as a Source of Protein.—The work of Walker (1925) and Martin (1925) for the most part corroborate the results previously noted regarding the value of sour skim milk as a source of protein for egg production. Martin states that "one gallon of skim milk has the same value for egg production as one pound of meat scrap." He further reports that both dried buttermilk and condensed buttermilk are efficient sources of protein when liquid skim milk or liquid buttermilk are not available on the farm.

Relative Value of Different Kinds of Milk.—Card (1926) found that sour skim milk, condensed buttermilk, fresh buttermilk and dried buttermilk were equally valuable in promoting growth in chickens. The work of Kistler, Charles and Knandel (1926) confirm the results secured by Card in respect to the use of condensed and dried buttermilk, the only two milk products used in this experiment.

Halpin, Johnson and Hart (1927), in tests on milk substitutes and barley in the Wisconsin chick ration, found that a mortality of 30.0 per cent occurred when meat scraps were substituted for milk. One-fourth and one-half substitutions resulted in a mortality of 6.6. per cent, whereas when dried skim milk was used the mortality was 3.5 per cent and when liquid skim milk was used there was no mortality.

Knandel and Charles (1928) fed dried skim milk in levels of 5, 10, 15 and 20 per cent of the basal ration and secured best results in egg production at the 10 and 15 per cent levels. Pederick and Clark (1928) secured better egg production during the fall and winter months (Australia) from pens fed dried milk than from pens fed meat meal, but for the remainder of the year meat meal proved to be more economical. Titus and Jull (1928) found that feeding sour skim milk produced an increased rate of growth in chicks during the first 15 to 18 weeks but no marked effect was observed in the calculated mature weights.

Whey, because of the minerals it contains, has some value as a feed for growing chicks and laying hens and may be used to good advantage, especially for moistening mashes, if it can be secured at a reasonable price.

MINERAL REQUIREMENTS

From Forbes (1909) we learn that Forster, a German physiologist, first proved that animals can live but a few days on feed that is practically free from mineral matter, and, strangely, "that animals will live longer if given no food at all." From Table 50 it is observed that approximately 3.5 per cent of the entire body of the chicken and of the dry matter in the egg, aside from the shell, is composed of mineral matter. Also, approximately 8.6 per cent of the dry matter of the body and approximately 35.6 per cent of the dry matter of the whole egg are composed of mineral matter. The shell constitutes approximately 10 per cent of the total weight of the egg and is composed almost entirely of calcium carbonate ($CaCO_3$). The need for mineral elements is extremely important even though most of the minerals are required in relatively small amounts.

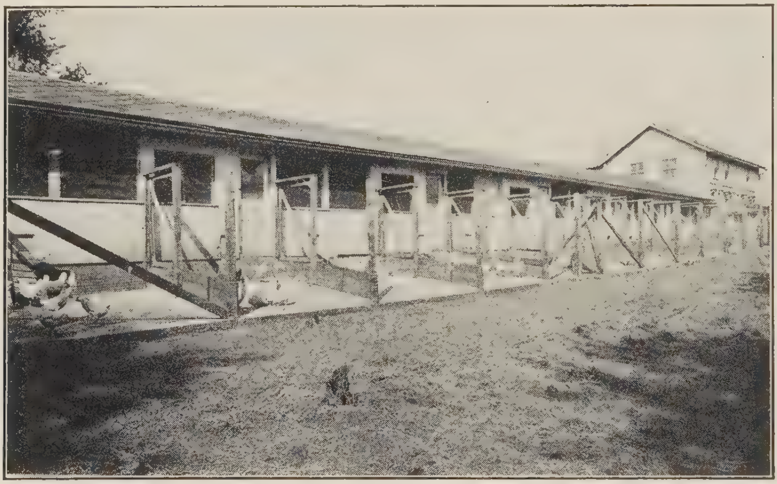

Fig. 149.—A long continous house used for experimental feeding purposes at the U. S. Animal Husbandry Experiment Farm at Beltsville, Maryland. (*Photograph by U. S. Dept. Agr.*)

It has already been observed, in discussing carbohydrate, fat and protein requirements, that many of the grains and most of the vegetable-protein feeds are deficient in minerals. Halnan (1924–1925) gives a very good illustration of the relative deficiency of the staple grains, such as wheat, in mineral nutrients.

> If we take the laying fowl as an example, we can estimate in a rough and ready fashion the extent to which certain classes of foods are likely to satisfy the requirements of the birds for egg production. The average egg (including shell) contains 3.04 g. of lime, 0.09 g. of sodium, and 0.06 g. chlorine. A bird fed on wheat alone would have to eat nearly 12 lb. of wheat to supply the lime required for one egg, nearly ½ lb. of wheat to supply the sodium required, and just over 3½ oz.

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to supply the chlorine required. Considering that the average food supply of fowl varies from 3 to 5 oz. of grain and mash per day, this example gives a striking emphasis to the necessity of providing an adequate balance of mineral constituents.

Among the various minerals mentioned on page 298, most of the experimental work conducted has involved a study of the deficiencies of poultry rations in calcium, phosphorus, sodium and chlorine. The chief sources of these and other minerals include raw or "green" and steamed bone, clam shell, oyster shell, limestone, rock phosphate, salt and iodine.

Bone in the raw or "green" state is very palatable and is quite rich in minerals, but can be used only locally and then to advantage only when it is properly ground. It is frequently relatively rich in protein of poor quality. Lippincott (1927) recommends feeding it at the rate of not in excess of one ounce per bird every other day.

Steamed bone meal is used quite extensively for the purpose of supplying phosphorus and lime. Wheeler (1903) observes that steamed bone meal is superior to rock phosphate for growing chicks. Bolte (1908) found that the addition of bone ash to vegetable concentrates was quite beneficial. He observes that "the phosphorus and lime in the rations are fully as necessary as the protein." Hartwell and Kirkpatrick (1911) and Hartwell and Lichtenthaeler (1914) observed that bone ash is superior to finely ground rock phosphate as a source of calcium phosphate for chicks. Lewis (1913) also found bone meal to be superior to the inorganic form of phosphate. Kistler (1925)observed that bone was superior to acid phosphate or raw rock phosphate in the production of eggs.

Clam shell is used to some extent as a source of calcium carbonate. Practically all of the results secured with clamshell and other products rich in calcium carbonate demonstrate that clam shell is relatively inferior. The Iowa Agricultural Experiment Station (1927) tested the relative value of oyster shell, limestone and clam shell as sources of calcium for egg production and secured an average egg production per bird of 104.0, 104.6 and 83.6 eggs, showing the inferiority of clam shell.

Oyster shell is a by-product of the oyster industry and is available in large quantities and serves as a source of calcium carbonate, which constitutes approximately 94 per cent of its total composition. Oyster shell contains iodine, which probably has a beneficial effect, especially in respect to feather growth.

That there is a close relationship between the number of eggs produced and the amount of oyster shell consumed is demonstrated by the very high correlation of 0.8724 ± 0.0079, obtained by Card (1916). Correlations between the weight of eggs produced and the amount of oyster shell consumed have been determined by Jull (1929*a*) for three groups of birds and are, respectively, 0.7385 ± 0.0334, 0.6225 ± 0.0432 and 0.4188 ± 0.0573.

Hart and Halpin (1920) found that oyster shell was superior to clam shell as a calcium supplement when the calcium level from both sources was equal. Kennard (1925) found oyster shells to be superior to limestone grit. Buckner, Martin and Peter (1925*a*) secured results that showed a distinct relationship between the calcium supply of the breeding hens and the hatchability of their eggs, hens receiving no oyster shell or other calcium supplements producing eggs very poor in hatchability. Alder (1927) found that calcite gave as good results in egg production as oyster shell.

Limestone is used principally as a source of calcium carbonate, which constitutes 93.71 per cent of its total composition, together with 1.39 per cent of magnesium carbonate, 0.76 per cent of calcium phosphate, and 4.24 per cent of organic substance, according to Wicke (1896). It should be observed, however, that limestones vary greatly in composition. Buckner, Martin and Peter (1923) observed that crushed limestone of good quality (non-magnesian) served as well as oyster shell as a source of calcium for laying hens. Dougherty and Gossman (1923) secured somewhat better egg production from a lot of layers which had free access to limestone grit than from another lot which had free access to both limestone grit and oyster shell. On the other hand, Hart, Steenbock and Morrison (1923) record better egg production from pens receiving oyster shell than those receiving limestone, clam shell, dry bone or quartz, respectively.

Buckner, Martin and Peter (1924) conducted experiments to determine whether such simple rations as corn and liquid buttermilk and corn and tankage supply sufficient calcium for normal egg production and to maintain the normal body balance of the laying hen. They found that the addition of calcium carbonate to both rations was essential and, from the standpoint of the value of limestone as a source of calcium carbonate, make the following observations:

> The hens receiving limestone produced larger eggs than those that did not receive it, and the hens receiving corn, buttermilk and limestone produced larger eggs than those receiving corn, mash containing tankage, and limestone, both the eggshell and the liquid part being heavier. Calcium carbonate (limestone) greatly increased the efficiency of buttermilk for egg production. Adding calcium carbonate (limestone) to a corn-buttermilk diet increased the weight of the eggshells nearly 40 per cent in one month, whereas withholding calcium carbonate from hens that had been receiving it with corn and buttermilk caused a decrease of about 20 per cent, in the same time. The addition of calcium carbonate (limestone) to a buttermilk-corn ration did not cause as large a deposition of mineral matter in the leg bones as when it was fed in connection with a tankage-corn ration. A diet of corn and buttermilk does not supply enough calcium

for satisfactory egg production and a diet of corn and mash, containing tankage, though containing more calcium than the corn-buttermilk ration, is even less efficient. Both must be supplemented liberally with calcium carbonate.

Rock phosphate supplies phosphate in the inorganic form and is reported by Wheeler (1903) to be of value as a supplement to rations containing no animal protein. Buckner, Martin and Peter (1923) observe that "Calcium in rock phosphate (tricalcium phosphate) can be utilized by the hen for the growth of bone but not for the formation of egg shell." The growth of bone in the lot given rock phosphate was greater than in the lots given oyster shell and limestone, respectively.

Salt is used as a source of sodium and chlorine, both of which are important in the feeding of chicks, but salt must be used in limited amounts. As a result of experiments in feeding different amounts of salt to laying hens, Wheeler (1907) recommended feeding it at the rate of 5 oz. per 100 lb. of feed but he advised against giving any salt to chicks less than 2 months old. Suffram (1909) reports a case of salt poisoning in fowls fed a mash of potatoes to which salt had been added. Zurn (1882) says that from ½ to 1 oz. will kill a healthy hen in from 8 to 12 hr. Pearl, Surface and Curtis (1915) report a serious case of salt poisoning resulting from the accidental feeding of salt with wheat.

The use of salt is supposed by some to increase the palatability of the ration, though Payne (1916) did not find such to be the case when he fed salt interchangeably to four different lots. Mitchell, Card and Carman (1926) fed five lots of chickens, 10 weeks old, well-balanced rations to each lot of which was added the following percentages of salt, 1, 2, 4, 8 and 1 plus free access to rock salt. No apparent detrimental effects were observed except that the lot receiving 8 per cent of salt made slower growth than the other lots. Tests to determine the toxic dose of salt indicated that the minimum lethal dose was approximately 4 to 5 g. per kilogram of live weight.

Iodine is reputed to have a value in the feeding of chickens, although practically no research work has been conducted to determine its value. It is the active constituent of the secretion of the thyroid gland, which has been demonstrated to have a pronounced influence on the physiology of metabolism. A deficiency of iodine in the feeding of mammals frequently leads to the development of goiter. Oyster shells contain iodine, which perhaps is one reason why they are superior to some other minerals also rich in calcium carbonate although birds have seldom been reported to have goiter. Hamilton and Kick (1928) fed 0.5 and 1 mg., respectively, of potassium iodide to different lots of chicks and failed to observe any influence on growth. Chaudhuri (1928) found that the iodine content of the thyroid glands in the chicken increases as they reach maturity and that the average content of the thyroid gland of the chicken is significantly higher than that of the mammal.

Mineral mixtures are used for mixing with mashes for growing chicks and adult birds, the practice resulting from the fact that some of the minerals are used in such small quantities that it is easier to mix the various minerals together first and then add the entire mixture to the mash.

Chick Mineral Requirements.—The need of the growing chick for minerals is different from that of laying hens. Jull (1915*a*) points out that growing chicks need calcium phosphate, while laying hens need calcium carbonate. Kaupp (1918) observes that in the growing chick there is a gradual increase in the requirements of calcium, magnesium, phosphorus and sulphur. Wheeler (1919) says that the mature hen can use the calcium in inorganic form whereas the growing chick is less able to do so. Wheeler also says that both calcium and phosphorus are more easily taken from the bones than from dead bone ash in the feed.

Importance of Calcium.—Calcium in calcium carbonate is used by the hen in the formation of both eggshell and bone, according to Buckner, Martin and Peter (1923) and a deficiency of calcium retards bone development and results in fewer eggs being produced but does not lead to the production of soft-shelled eggs. In 1924 the same authorities add that a deficiency of calcium in the diet causes a general depletion of the body material of the laying hen and a general decline in vigor.

Calcium in the Eggshell from Calcium in the Blood.—The calcium content of the blood of chickens of both sexes and of various ages was determined by Hughes, Titus and Smits (1927). It was found that calcium content of the blood in milligrams per 100 cc. was as follows: from hatching time to maturity, from 12 to 14; mature pullets not laying, 20; mature pullets laying, 27; capons, mature cockerels and molting hens not laying, about 12 to 14; hens after molting and in lay, 31. The authors believe that the increase in the calcium content of the blood, in relation to age, sex and state of laying, is due to the work of the secretions of some of the internal glands that are associated with the development of the secondary sexual characters.

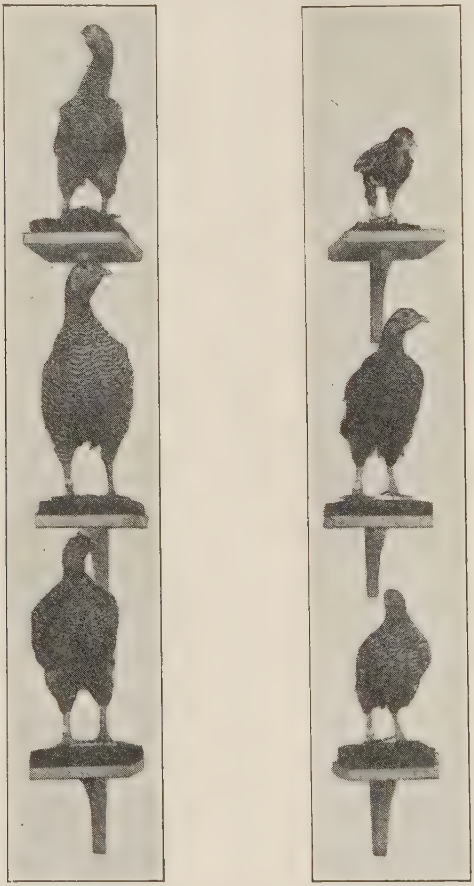
Buckner, Martin and Peter (1925*d*) made a chemical analysis of the oviduct of the hen for calcium oxide and phosphorus pentoxide. Only small amounts of calcium oxide were found, although the amounts were significantly greater in hens in laying condition. The phosphorus pentoxide increased in amounts as the rest period approached. Because of the relatively small amounts of calcium oxide present, the authors conclude that the calcium in the eggshell must come from the calcium in the blood.

Calcium from the Feed.—Halnan (1925*a*) reports that egg laying is not preceded by a long storage of calcium but that the demands of the bird for calcium during egg production are met, almost entirely, by increased retention of calcium from the available supply in the feed.

He also says that the metabolism of phosphorus in the bird is linked with that of calcium and that excessive calcium feeding may lead to the depletion of phosphorus reserves. This is a point of considerable importance in the feeding of laying stock. Buckner, Martin and Peter (1925*b*) made analyses of the droppings of laying hens with and without a calcium carbonate supplement (oyster shell) in the diet and found that the percentage of calcium oxide in the ash of the droppings showed a distinct reduction in the lots not receiving oyster shell, little or no carbonates being present, indicating that all of the calcium carbonate available in the feed was being utilized for eggshell formation. Complete analyses of the constituents of the ash showed that the greater part of the calcium in the droppings of the hens not receiving oyster shell was present not as carbonate but as phosphate, which is not available for formation of eggshell.

Effect of Calcium Supply on Eggs.—Buckner, Martin and Peter (1925*c*) observed that a calcium carbonate supplement to the laying ration produced an increase in the average weight of the contents of the egg, the increase being divided nearly equally between the yolk and the white. On the other hand, the average percentage of protein and calcium oxide in the contents of the egg did not seem to be affected. Calcium limitation in the ration, however, results in the production of thin-shelled eggs, as demonstrated by Buckner and Martin (1920). In this connection it is interesting to note from the work of Delezenne and Fourneau (1918) that during the process of incubation approximately 75 per cent of the calcium of the mature chick embryo comes from the eggshell.

Effect of Calcium Supply on Chicks Hatched.—In a determination of the calcium and phosphorus content of chicks hatched from lots of hens given range and fed oyster shell, confined and fed oyster shell, and confined and not fed oyster shell—Buckner, Martin and Peter (1926)—it was found that the dry weights of the chicks were considerably heavier from the hens given oyster shell. At hatching time the chicks from each lot were classified as strong and weak, according to their apparent vigor. Although the phosphorus content was practically the same in weak chicks as in strong ones, there was less calcium in the weak chicks. The strong chicks from the lot given range and fed oyster shell contained more calcium than the strong chicks from the other lots, indicating that the range supplied something not available to the birds in confinement. Also, the chicks from the lot given range absorbed more calcium carbonate from the eggshell during incubation than the chicks from the other lots. More recent work by the same authors (1929) confirms the results secured previously and, in addition, they found that feeding hens calcium carbonate (limestone, oyster shell) as a supplement to a ration of yellow corn, wheat and liquid buttermilk, fed *ad libitum*, together with cabbage, lettuce and other green feed fed twice weekly, resulted in larger chicks being hatched and a higher ratio of the weight of the moisture-free carcass of the chick to the original weight of the contents from the egg than when the ration was fed without the calcium carbonate.



Left Right

Fig. 150.—The only difference in the rations of the upper left and right chicks is that the chick in the upper left received sunlight which was denied the upper right chick. The middle right chick shows the result of a deficiency of minerals in the diet as compared with the middle left chick, both chicks being reared in the absence of sunlight. The lower right chick shows the effect of vitamin-*A* deficiency in the presence of sunlight as compared with the lower left chick. (*Photograph by Wis. State Coll. Agr.*)

Various Mineral Mixtures Tested.—The results of the various lines of investigational work with minerals demonstrate that calcium, phosphorus, sodium and chlorine as well as perhaps iodine are among the minerals that are most frequently deficient in rations prepared for feeding chickens. These are usually supplied in mineral mixtures.

Kennard, Holder and White (1922, 1923) found that a mineral mixture of 60 parts of bone ash, 20 parts of calcium carbonate, and 20 parts of sodium chloride was superior to more complex mineral mixtures in providing mineral supplements to grain rations. They say that the ration should not contain more than 2 per cent of the mineral mixture.

Hart, Steenbock, Halpin and Johnson (1924) secured very good results from a mineral mixture consisting of 5 parts raw bone, containing approximately 50 per cent of calcium phosphate, 5 parts of pearl grits, which supply calcium carbonate, and 1 part common salt, this mineral mixture being added to a grain ration of 80 parts of yellow corn and 20 parts of wheat middlings, skim milk being given as a drink instead of water.

In experiments with growing chicks and laying hens, Orr, Moir, Newbigin, Robertson and Murphy (1925) found that a mineral mixture consisting of 50 per cent of bone meal, 20 of common salt, 20 of chalk, 5 of sulphur, 5 of iron oxide and a trace of iodine gave significantly better egg production than when the mixture was not added to the ration. Similar results were secured by Orr, Moir, Kinross and Robertson (1925) in three series of experiments conducted in England, Scotland and Ireland.

The most satisfactory mineral supplement to soy-bean oil meal, which was added to the ration as a source of protein, was determined by Philips and Hauge (1925) to be a mixture of 24 parts of limestone, 15 parts of salt, and either 21 parts of soluble bone, 22 parts of steamed bone or 42 parts of acid phosphate.

That an excess of mineral supplements in rations for growing chicks is harmful was determined by Mussehl, Blish and Ackerson (1927). The basal ration consisted of yellow corn meal, ground wheat, yeast, cod-liver oil, meat and bone meal and cornstarch. All lots of chicks were irradiated with a quartz mercury vapor lamp twice weekly for about one hour. It was found that adding calcium carbonate, or raw bone meal or a mixture of these with common salt served to retard growth.

Mussehl and Marsden (1927) fed a mineral mixture consisting of 3 parts raw bone meal and 1 part each of ground limestone and common salt to fattening chickens receiving a basal ration of 60 parts of yellow corn meal and 40 parts of white shorts, moistened with fresh buttermilk. This mineral mixture prevented the development of weak bones. Experiments by Hart, Steenbock, Kletzein, Halpin and Johnson (1927) indicated that the calcium-phosphorus ratio in the ration of growing chicks can be varied as much as 7:1 without affecting bone development, providing there is plenty of vitamin D in the ration. On the other hand, Bethke, Kennard, Kick and Zinzalian (1929) observe that the optimum or nearly optimum ratio of calcium to phosphorus lies between 3:1 and 4:1. When it exceeded the latter ratio, growth decreased and the vitamin D requirements increased.

Experiments with chicks at the Ohio Agricultural Experiment Station (1928) showed "that the calcium in calcium carbonate, calcium sulfate, calcium lactate, tricalcium phosphate, dicalcium phosphate, oyster shells, high calcium limestone, dolomitic limestone, bone meal, and certain rock phosphates was equally available as judged by the ash in the bones. The basal ration with which these supplements were fed contained 0.5 per cent of cod-liver oil, and each supplement was so fed that the calcium intake equaled the calcium in 2 per cent calcium carbonate." Buckner, Martin and Peter (1928) conducted experiments with laying hens, using calcium carbonate, calcium sulfate, calcium lactate and calcium chloride as supplements to a ration of wheat and corn with liquid skim milk available at all times and green feed fed twice a week. Calcium carbonate proved to be the most valuable supplement. For growing chicks, Buckner and Martin (1929) found that calcium carbonate and calcium sulfate serve equally well as sources of calcium for the development of bone. They also found that tricalcium phosphate was as valuable as a source of calcium and that it supplies phosphorus in addition. Mussehl, Hill, Blish and Ackerson (1930) found that calcium furnished as tricalcium phosphate was more efficiently utilized by growing chicks than was an equivalent amount of calcium furnished as the carbonate, lactate, sulphate or chloride with a basal ration of yellow corn meal 50 per cent, shorts 24 per cent, casein 10 per cent, blood meal 5 per cent, cod-liver oil 2 per cent, yeast 3 or 4 per cent and starch 5 or 6 per cent.

VITAMIN REQUIREMENTS

Whereas the chief value of the carbohydrates, fats, proteins and minerals is determined by the kind and amount of the nutrients they provide, the chief value of the vitamins is determined largely by the physiological effects they produce in the digestion, assimilation and utilization of the nutrients. Vitamin-rich supplements supply some nutrients, of course, but they exercise a physiological effect out of all proportion to their relative bulk in the ration.

During recent years considerable experimental work has been undertaken to determine the requirements of chickens for the various vitamins. Considerable of the research work was stimulated by virtue of the fact that it had been demonstrated that chickens could be reared and kept indoors, a thing impossible only a few years ago. It has been noted on pages 299 to 302 that vitamins A, B, D and possibly E are important in poultry nutrition, vitamin B here being regarded as the antineuritic vitamin. It may be that the letter F will be used to designate the antineuritic vitamin and G the antipellagrous vitamin, in which case vitamin F would probably have the same significance in poultry nutrition now held by vitamin B. So far as has been determined, vitamin C, the antiscorbutic vitamin, is not important in the feeding of chickens.

Sources of Vitamin A.—Osborne and Mendel (1913) found cod-liver oil to be an excellent source of vitamin A. Holmes (1923, 1924) found that plump cod yielded more vitamin A than emaciated cod. He found no difference in the vitamin A content of cod-liver oil in samples made from fresh livers and from livers stored at low temperatures and out of contact with the air for six months and a year, respectively. On the other hand, the oil from the stored livers was decidedly less palatable than the oil from the fresh livers. Zilva, Drummond and Graham (1924) found that neither the age of the cod nor its condition in the sexual cycle affected the vitamin A content. Those desiring further information regarding cod-liver oil should consult the excellent bibliography by Manning (1929).

Davis and Beach (1926) observe that salmon oil compares favorably with cod-liver oil as a source of vitamin A. McCollum and Simmonds (1927)[1] observe that "The livers of fish do not serve as a storehouse of carbohydrate (glycogen) as do the livers of mammals, but are loaded with fat when the fish are in prime condition. All liver oils from fishes thus far studied have been shown to be excellent sources of vitamin A." The same authors point out that Hart found that over 90 per cent of the vitamin A content of whole milk is removed in the skimming process.

Egg yolks were shown to be rich in vitamin A by McCollum and Davis (1913). Palmer and Kempster (1919*c*) found pig liver to be rich in vitamin A when fed to chicks previously reared on a diet deficient in this vitamin. Cruickshank (1927) and Cruickshank, Hart and Halpin (1927) showed that cod-liver meal when fed to chicks in fairly liberal amounts did not prevent the development of a respiratory and lung trouble, accompanied by nodular lesions of the mouth and the pharynx, which are characteristic pathological developments resulting from vitamin A deficiency in the diet. They conclude that cod-liver meal is not a good source of vitamin A.

Beach (1923) observed that green grass is relatively rich in vitamin A and the results of other investigators have shown that alfalfa hay, alfalfa leaf meal and clover hay also contain vitamin A. Results secured at the Oklahoma Agricultural Experiment Station (1923–1924) and results secured by Hart, Steenbock and Lepkovsky (1924) show that yellow corn is a good source of vitamin A, and Davis and Beach (1925) found that green alfalfa, green barley, sprouted barley, red clover, kale, blue grass, and carrots are good sources of vitamin A, while mangel beets are valueless. Davis and Beach (1926) also found that yellow and red carrots are as good sources of vitamin A as the common varieties of green feed used in feeding poultry.

Vitamin A Requirements.—A great deal of work has been done to determine the vitamin requirements of chickens for growth, fattening and egg production. Among the first results secured showing the deficiency of vitamin A in the diet of chickens were those of Hart,

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[1] McCollum and Simmonds, "The Newer Knowledge of Nutrition." By permission of The Macmillan Company, publishers.

Halpin and Steenbock (1917), who showed that birds on a low vitamin A diet did not do well and there was an accumulation of urates in the ureters.

Harring, Beach and Jaffa (1919–1920) have reported cases of what they called "nutritional roup" which apparently were not infections but were due to a lack of green feeds (presumably vitamin A) in the diet. Emmett (1920), Gurerrero and Conception (1920) and Beach (1921) observed the development of xerophthalmia (a pathological condition of the eyes) in birds fed a diet deficient in vitamin A. Emmett and Peacock (1922, 1923) demonstrated that growing chicks require vitamin A, and Mitchell, Kendall and Card (1923) have shown that the vitamin A requirements of chicks are relatively high.

Hamburger and Collazo (1923) showed that feeding cod-liver oil has a regulating influence on fat metabolism, enhancing fat resorption, and there is a reduction in the concentration of fat in the blood.

Hart and his coworkers (1924) fed one lot of chicks a ration consisting of 97 per cent white corn, 2 per cent calcium carbonate and 1 per cent salt and another lot the same ration except that yellow corn replaced white corn. Both lots received skim milk *ad libitum* and were exposed to sunlight. The lot receiving yellow corn did much better, demonstrating the relatively high content of vitamin A in yellow corn as compared with white corn.

Hauge, Carrick and Prange (1927) observed that a ration for chicks otherwise deficient in vitamin A, made good growth up to 10 weeks of age when the ration contained 25 per cent yellow corn, but, after 10 weeks, better growth was secured when the ration contained 50 per cent of yellow corn.

Orr and Maciver (1924) fed a mixed grain ration to laying hens and secured results that showed that only small amounts of cod-liver oil are needed to supplement normal rations and that if too much is used egg production is decreased. Similarly, Orr, Crichton and coworkers (1924) found that adding cod-liver oil to normal rations for growing chicks and laying hens did not result in any improvement in growth, laying or hatching.

Shutt (1925) studied the influence of feeding cod-liver oil on the deposition of lime compounds in the eggshell and secured negative results.

Holmes and his coworkers (1927) fed 0.25, 0.5, 1.0 and 2.0 cc. of cod-liver oil per bird per day and noted that as the cod-liver oil was increased there was an increase in egg production, egg weight, fertility, hatchability, viability of chicks hatched and in the vitamin potency of the eggs laid. For chickens fed on white rice and yeast or on corn with fish meal as the protein supplement, Plimmer, Rosedale and Raymond (1927) found that 0.5 per cent of cod-liver oil was the minimum requirement. Since cod-liver oils vary in their vitamin A content, however, these authors recommend feeding 1 per cent of cod-liver oil in the ration.

Sources of Vitamin B.—Coöper (1912, 1913) studied the relative value of feedstuffs for the prevention of polyneuritis in birds and observed the following results, expressed in terms of grams of fresh substance per day to prevent the disease: egg yolk, 3; ox liver, 3; ox cardiac muscle, 5; cheese, more than 8; fish muscle, more than 10; ox muscle, 20; cow's milk, more than 35. Among animal tissues, egg yolk and ox liver are relatively rich in vitamin B. In 1914 Cooper observed that autolyzed yeast had the properties of curing polyneuritis in birds.

McCollum, Simmonds and Pitz (1916) found the wheat germ to be exceptionally rich in vitamin B. Osborne and Mendel (1920) found that alfalfa and clover leaves were richer in vitamin B than tomato, spinach, cabbage or turnip, though each of these products contained some. Plimmer, Rosedale and Raymond (1923*a*) studied the value of yeast products, dried yeast, oatmeal and dried skim milk as sources of vitamin B for chickens and obtained the relative values of 100 for marmite (a yeast extract), 50 for dried yeast, 7.9 for oatmeal and 6.7 for dried skim milk.

The same authors in 1926 demonstrated the superiority of wheat germ over wheat bran and wheat middlings as a source of vitamin B and found that bran and middlings were superior to flour largely because of the amount of the germ present. Again in 1927, the same authors together with Lowndes found that when dried yeast is valued at 100 in respect to its vitamin B content other values were as follows: wheat germ, 66; bran and middlings, each 12–13; whole wheat, 8–10; corn, 7–8; oats, 4–5; oatmeal, 4.

Hovarth (1927) observed that turnip juice contained sufficient vitamin B to cure mild cases of avian polyneuritis. Many other products contain vitamin B in varying proportions; in fact, it is fairly widely distributed among the feeds used for poultry.

Vitamin B Requirements.—Eijkman (1890) was probably the first to observe the development of a disease among chickens fed on an exclusive diet of polished rice. The disease resembled beriberi which affects humans and was later found to be due to a deficiency of vitamin B. When the pericarp and the germ or embryo of the rice kernel were added to the diet of polished rice, the chickens were cured of polyneuritis. Polished rice is deficient in vitamin B whereas the pericarp and the germ contain it. Many other investigators have confirmed the observation of the development of polyneuritis in chickens when the diet is deficient in vitamin B.

Plimmer and Rosedale (1922) found that chickens require vitamin B for normal development and Plimmer, Rosedale and Raymond (1923*c*) found that chickens require more than pigeons and that ali other kinds of domestic fowl require more than the chicken. Souba (1923*b*) observed that "Single-comb White Leghorn cockerels, on a diet deficient in vitamin B and apparently adequate in all other particulars, showed a decrease in the size and weight of organs in the following order: testes, spleen, heart, liver, kidneys, pancreas and thyroid gland." Souba also observed that the presence of vitamin B in the diet tended to increase the consumption of feed.

Souba, Knandel and Dutcher (1924), in experiments on the feeding of dried yeast to laying pullets and hens, were led to believe that the addition of vitamin B did not improve egg production with birds on range and receiving a "good" ration while, among pens where artificial lights were used, those receiving vitamin B laid more eggs and the eggs were larger than those not given vitamin B. In experiments on raising chicks, Knox and Lamb (1924) obtained favorable results with yeast, due, they believed to supplementing proteins or other factors as well as to the vitamin B content.

That the germ of the corn kernel contains vitamin B has been demonstrated by Carrick (1925*b*). Birds fed on degerminated white corn were observed by Carrick and Carr (1925) to lose their appetites but to regain them upon being fed yeast.

Unnecessary for Chicks Outdoors.—Vitamin B added to the ration proved of value in the case of chicks raised indoors by Hogan, Guerrant and Kempster (1925*a* and *b*) though Orr and his coworkers (1925) observed that poultry kept under natural conditions and fed a well-balanced ration do not need any additional vitamin B. Mussehl and Bancroft (1925) confirm the latter observation. Krauss (1925) secured results with chicks grown indoors up to 8 weeks of age that indicated that the addition of 0.5 per cent of yeast to a "standard scratch and mash" ration produced an increase in mortality.

Hamilton, Card and Kick (1927) found that the addition to a mixed grain ration of vitamin B in the form of yeast and alfalfa leaves did not improve the ration for chicks grown outdoors but yeast improved the rations slightly with chicks grown indoors. Cassel (1927) found that supplements of yeast to the Washington State commercial laying ration, including cabbage in the fall, rutabagas in the winter and fresh green alfalfa in the spring and summer, did not improve egg production. It seems probable that such a ration in itself should contain abundant supplies of vitamin B particularly since the scratch ration consisted of two-thirds wheat and the mash ration contained liberal amounts of middlings.

Dougherty (1928) tested the value of 5 per cent of pure dried yeast as a part of a basal ration composed of whole grain, mash and fresh greens and found that the birds' appetites were stimulated, feed consumption increased and growth stimulated. On the other hand, Bethke and Kennard (1928), in the case of chicks brooded on wire floors and given a ration containing 63 per cent or more of ground whole corn and wheat, 10 per cent of soy-bean oil meal and wheat bran, and 20 per cent of either meat scraps or dried buttermilk, with adequate mineral and fat-soluble supplements, found that supplements of vitamin B were ineffective.

Balancing Effect.—Plimmer, Rosedale and Raymond (1927*b*) found that the protein, carbohydrate and fat in the diet need balancing with vitamin B. Rosedale and Oliveiro (1928) demonstrated the presence of certain enzymes in the potent curative extract of rice polishings. Evans and Lepkovsky (1928) report that fat has a sparing action on vitamin B, since animals receiving an almost fat-free diet require a higher level of the antineuritic vitamin to establish any definite level of growth than if fat be added to the diet.

Vitamin C Not Required.—The principal sources of vitamin C, which prevents the development of scurvy in mammals, include the citrus fruits, tomatoes, growing shoots, fresh green leaves, roots and tubers.

That vitamin C is not required as a supplement in the diet in poultry nutrition has been demonstrated by Mitchell, Kendall and Card (1923), Plimmer, Rosedale and Raymond (1923*b*), Carrick and Hauge (1925), Orr, Moir, Kinross and Robertson (1925), Hart, Steenbock, Halpin and Lepkovsky (1925), although Hauge and Carrick (1926) were led to believe that the chick requires vitamin C but that it is able to synthesize it within its own body.

Sources of Vitamin D.—Numerous investigators have established the fact that cod-liver oil and egg yolk constitute the most readily available sources of vitamin D for poultry feeding purposes. Collier (1924) prevented the development of leg weakness in chicks reared in confinement by feeding them hard-boiled eggs. Bethke and Kennard (1924–1925) demonstrated the value of cod-liver oil in the rearing of chicks indoors. Hughes, Titus and Witham (1925–1926) found that green alfalfa and green oatsprouts supply small quantities of the vitamin but not enough to prevent the development of leg weakness unless the chicks were exposed to sunlight or to ultra-violet light.

Heuser and Morris (1926, 1926–1927) found that different brands of cod-liver oil vary significantly in their vitamin content. They also found that with plenty of calcium and phosphorus in the ration, the amount of cod-liver oil necessary to prevent the development of rickets depends upon the antirachitic potency of the oil and the amount of this factor stored in the body of the chick at the time of hatching. In their experiments only tested oils provided complete protection against rickets.

Hess and Weinstock (1926) found the oil of the liver of the puffer fish to be at least fifteen times as potent as the most active specimens of cod-liver oil.

Bethke (1926) studied the relative value of three brands of cod-liver meal as sources of vitamin D and found that they varied considerably though they were all inferior to cod-liver oil. Cruickshank, Hart and Halpin (1927) concluded that cod-liver meal contains sufficient vitamin D to promote good calcification in bone when fed at a level of 1 per cent of the ration. Stuart (1928) observed that not only did cod-liver meal give as good results as cod-liver oil, but that a ration containing 5 per cent of fish meal also prevented the development of rickets over a period of 8 weeks. On the other hand, Mussehl, Hill, and Ackerson (1928) secured results that led them to conclude that a ration containing 5 per cent of cod-liver meal did not provide sufficient vitamin D to prevent the development of rickets. It is highly probable that the part of the fish used in the manufacture of cod-liver meal and fish meal has an important bearing on the antirachitic properties of the meal. Fish muscle is much lower in vitamin D than certain parts of the viscera.

Davis and Beach (1928) experimented with salmon oil extracted from cannery refuse (containing viscera) and found that a mixed grain ration containing 2 per cent of the salmon oil prevented the development of rickets.

The irradiation of liver meal, yellow corn and white corn did not enhance their antirachitic properties, as determined by Mussehl, Hill and Rosenbaum (1928), but fresh corn germ oil was improved slightly.

Vitamin D Requirements.—Although a vast amount of work has been done to determine the requirements of growing chicks and laying hens for vitamin D, it is well to observe at this point that such work has been stimulated in large measure by the demand for rations that would grow chicks successfully indoors. When the ration for growing chicks is deficient in vitamin D and when the chicks are deprived of access to the direct rays of the sun, calcification of the bone does not take place normally.

Among the first to demonstrate that chicks develop leg weakness or rickets when grown indoors on diets deficient in vitamin D were Osborne and Mendel (1918), Hart, Halpin and Steenbock (1920, 1922). Dunn (1924*e*, 1924*f*) secured results that led him to believe that cod-liver oil absorbed by starch and kept in the dark for 6 months loses its potency of vitamin D through oxidation, but the stability of cod-liver oil against vitamin D oxidation has been demonstrated by Hart, Steenbock and Lepkovsky (1925).

Bethke and Kennard (1924–1925) succeeded in rearing chicks indoors for over 8 months with a ration which contained cod-liver oil to the extent of 2.5 per cent of the ration, though the shanks remained pale. Hogan, Guerrant and Kempster (1925*b*) fed synthetic diets to chicks in confinement and observed a type of leg weakness which they believed was not associated with a lack of vitamin D.

The influence of vitamin-D deficiency on gaseous exchange in chicks was studied by Baldwin, Nelson and McDonald (1928), who found that the respiratory quotient was decreased through vitamin D deficiency. An adequate diet produced a respiratory quotient of between 0.94 and 1.00 whereas a rachitic diet produced one of 0.70 and it remained low during the period at which rachitic symptoms were apparent and during this period the body temperature was also low. An adequate supply of vitamin D would appear to be necessary to maintain a normal respiratory quotient in chicks.

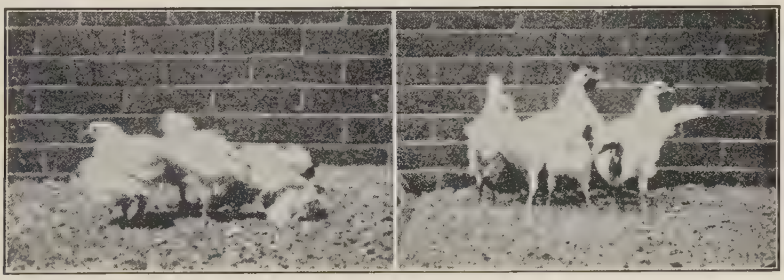


Fig. 151.—The effect of exposing chicks, afflicted with leg weakness, to 15 minutes' direct sunlight, daily, for 4 weeks. Left, before exposure. Right, after exposure. (*Photograph by Bethke and Kennard*, 1927.)

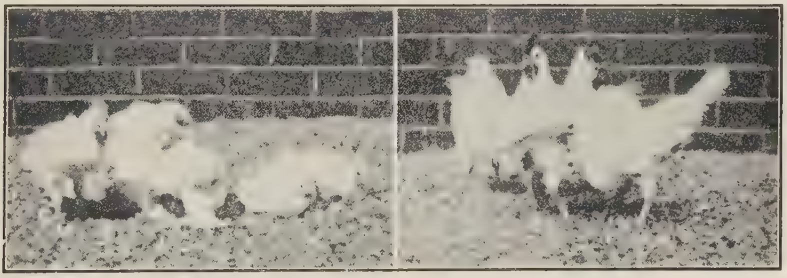


Fig. 152.—The result of exposing chicks, showing signs of leg weakness, to 15 minutes' sunlight through a "screen-glass" substitute, daily, for 4 weeks. Left and right, before and after treatment, respectively. (*Photograph by Bethke and Kennard*, 1927.)

Sunlight and Ultra-violet Light in Relation to Vitamin D Requirements.—That sunlight and the ultra-violet rays have the same effect as vitamin D in preventing the development of rickets in chicks was probably first demonstrated by Hart, Steenbock, Lepkovsky and Halpin (1923, 1924*b*). Hughes (1924) found that ultra-violet light has the same effect as sunlight in preventing the development of rickets in growing chicks. Hughes and Payne (1924) secured much better egg production, a higher calcium content in both shell and egg, and better hatchability from a pen of laying hens subjected to ultra-violet light for 10 min. every day as against the control pen.

Relative Value of Sunlight and Ultra-violet Light.—The results of experiments conducted by Murray, Little and Bovie (1924) demonstrated the superiority of sunlight and ultra-violet light over cod-liver oil in respect to the development of bone in growing chicks, while chicks raised under ordinary window glass showed the development of leg weakness in 5 weeks. Mussehl and Bancroft (1924–1925) secured better growth by exposing growing chicks to 45 min. of sunlight daily than by adding as much as 3 per cent cod-liver oil to the ration. Hughes, Payne and Latshaw (1925) found that direct sunlight gave somewhat better results in egg production than ultra-violet light, and Hughes, Nitcher and Titus (1925) observe that the beneficial action of ultra-violet light in preventing rickets in growing chickens is due to its direct action on the chickens.

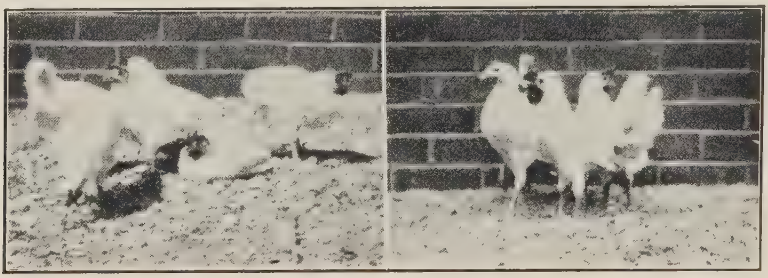


FIG. 153.—The effect of 15 minutes' daily exposure to sunlight transmitted by a "fabric-glass" substitute, on chicks afflicted with leg weakness. Left, before exposure; right, 4 weeks after exposure. (*Photograph by Bethke and Kennard,* 1927.)

Ackerson, Blish and Mussehl (1925) observed that both calcium and inorganic phosphorus were higher in the blood of normal chicks than in chicks of the same age suffering from rickets. Hart and five coworkers (1925) found that subjecting laying hens to ultra-violet light daily for 10 min. led to a marked increase in the calcium content of the shell as compared with control hens, and the developing embryos from the irradiated hens contained, after 21 days of incubation, nearly twice as much calcium as the embryos from the non-irradiated birds. Furthermore, the antirachitic potency of the egg yolks from irradiated hens was approximately ten times that of the egg yolks from the non-irradiated hens. The antirachitic vitamin content of eggs from hens subjected to ultra-violet light for 30 min. daily as compared with hens not treated was determined by Hughes, Titus and Moore (1925). The eggs from the treated hens proved to be a better source of the antirachitic factor when fed to chicks than the eggs from the untreated hens, although the eggs from the treated hens did not prevent the development of rickets in the chicks.

Walther (1926) conducted experiments on the irradiation of young hens and found that marked effects were obtained only when maintenance conditions were subnormal.

Length of Time to Irradiate.—In a test to determine the proper length of time to subject growing chicks to ultra-violet light in order to prevent the development of rickets, Goodale (1926) found that irradiation periods of from 1 to 10 min. twice weekly promoted normal growth and prevented the appearance of leg weakness. Heuser and Norris (1929) found that an average exposure of 10.9 min. daily to sunlight was sufficient to produce normal growth and to prevent the development of rickets in growing chicks. Irradiation for 9.1 min. daily with a quartz mercury vapor arc was sufficient for normal growth, but some indications of rickets developed so that 13.7 min. daily irradiation was necessary for complete protection. There were no indications of any differences from exposure to sunlight and to the quartz enclosed mercury-vapor arc, but repeated tests indicated that chicks exposed to sunlight had greater vigor and smoother plumage.

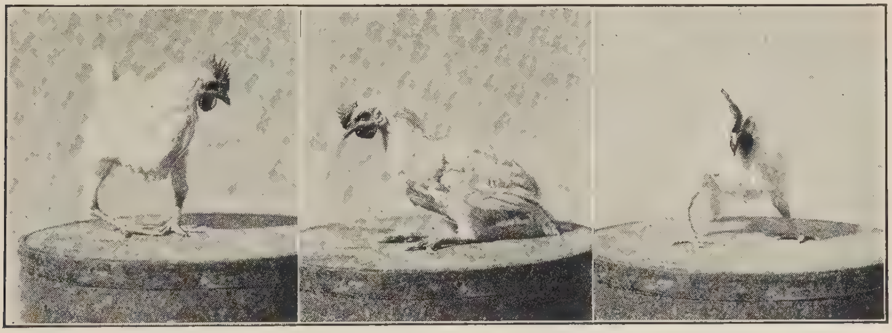


FIG. 154.—Typical cases of leg weakness, due to a deficiency of Vitamin D in the diet. (*U. S. Dept. Agr.*)

The Irradiation of Feeds.—The irradiation of feeds instead of the chickens has been investigated by a number of workers. Acting on the results secured by Hess and Weinstock (1924) and Steenbock and Daniels (1925) in the irradiation of feeds for other animals, Mussehl (1926) irradiated liver meal, yellow corn, white corn and fresh crude corn oil. Negative results were secured with the possible exception of fresh crude corn oil. Klein (1927) irradiated cottonseed oil and secured negative results. Mercer and Tozer (1927) also secured negative results from irradiated cholesterol fed to laying hens given access to grass yards. Auger (1928), however, found that the irradiation of feeds for laying hens during the winter months in France resulted in better egg production as compared with control hens.

Glass Substitutes.—The rearing of chicks indoors and the keeping of laying hens confined continuously have stimulated research along the lines of determining the extent to which ultra-violet light is transmitted through glass substitutes, since ordinary glass excludes practically all of the ultra-violet light. The use of the sun as a source of light has certain advantages over the feeding of materials rich in vitamin D or irradiating the birds. During recent years there has appeared on the market a number of glass substitutes, some of which have been demonstrated to be permeable to various amounts of ultra-violet light. The actual per cent of transmission of ultra-violet light permitted by some of these substitutes has been determined by the Bureau of Standards of the U. S. Department of Commerce (1928). Biological tests with some of the substitutes have been reported by the Council on Physical Therapy of the American Medical Association (1927). Coblentz and Stair (1929) give the results secured after conducting thorough tests on ultra-violet solar radiation and the solarization of window materials.

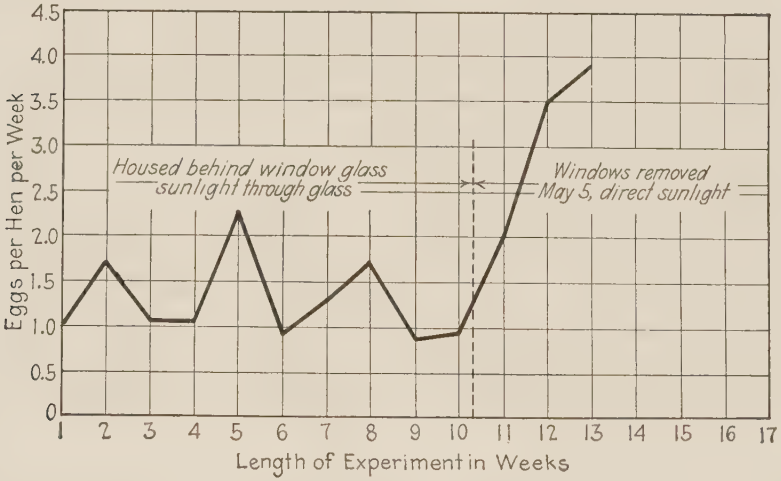


Fig. 155.—Laying hens require sunlight. This graph shows the results of another experiment at this station, running from February 21 to May 23. Note that the windows were removed May 5 and that egg production rapidly increased. (*After Kempster, Mo. Agr. Exp. Sta.*)

A number of experiments have been conducted to determine the relative value of some of the glass substitutes in the prevention of rickets. Bethke and Kennard (1926) compared direct sunlight with sunlight transmitted through window glass and celo glass and found that rickets developed in the "window-glass" chicks in 5 weeks whereas the "sunlight" and "celo-glass" chicks showed no rickets during the 10-week period of the experiment. The same authors (1927*b*) observed that "screen glass" and "fabric glass" prevented the development of rickets for a period of 9 weeks.

Wood (1926–1927) found that celo glass allowed normal growth and prevented the development of rickets in growing chicks. He suggests that the value of a glass substitute depends upon its power to transmit ultra-violet light, the season of the year and the amount of sunlight during the midday hours. Hart and five coworkers (1927) have shown that where glass substitutes have had 10 min. daily exposure to the rays from a quartz mercury lamp, the transmission of ultra-violet light has been practically as good as direct irradiation. Also, 3 min. per day and as low as 3 min. per week have brought about an improved calcium assimilation in comparison with ordinary window glass, but not as effective assimilation as that secured with direct irradiation.

Russell and Massengale (1927–1928) observed that winter sunlight in New Jersey transmitted through celo glass was effective in preventing leg weakness. Cochran and Bittenbender (1928) tested the value of sunlight transmitted through celo glass, flexo glass, glass cloth, glass fabric and window glass as compared with direct sunlight. Direct sunlight proved to be the best preventive against leg weakness but this condition did not develop when sunlight was transmitted through celo glass, flexo glass and glass fabric, although it was found that there was comparatively little leg weakness among the "window-glass" chicks.

Wheeler (1929) tested the effect of winter confinement on egg production and hatchability and drew the following conclusions:

> Hens of sound stock, reared in the open and allowed to be out of doors on the occasional fair days until November or December, are prepared for two or three months' confinement under the ordinary limited lighting conditions of winter. Under standard rations of ordinarily available foods such hens have maintained good egg production and good health until the time when milder weather usually permits occasional access again to the open air.
>
> The general breakdown which comes when hens have been for too long deprived of unfiltered sunlight has not occurred when hens have had a few hours' access to open sunlight once every ten days, or at even longer intervals, or when they have had access to reflected sunlight every fair day. Normally good results in egg production and in hatching have been maintained, then, throughout the entire laying season.

Parathyroids and Rickets.—Practically all of the results of the experiments on rickets reported previously have had to do with the prevention of or development of rickets in growing chicks. That rickets may occur in mature chickens, however, has been demonstrated by Doyle (1925). There are marked changes in the ribs and other bones of the body of the rachitic birds as compared with normal birds and the parathyroid glands are greatly enlarged. The parathyroid glands are small internal (endocrine) glands which lie at the caudal angle of each thyroid lobe, at the base of the chicken's neck.

Higgins and Sheard (1928) experimented with chickens, exposing different groups of them to sunlight from which the ultra-violet, red-yellow and green-blue rays, respectively, had been removed by special glass filters. At the same time, all the chickens were fed a diet rich in everything except vitamin D. The authors drew the following conclusions:

Light of certain wave-lengths appears to bear a definite relationship to the physiology of the parathyroid glands. In the absence of the optimal light factors, an attempt is made by the organism to compensate for this loss by an increase in the total functional activity of the gland. Hyperplasia ensues in the absence of the lesser wave-lengths of sunlight but such hyperplasia is partially obviated by the addition to the diet of a small portion of cod-liver oil. These experiments indicate that normal development of the parathyroids will best maintain in the presence of both the lesser and the greater wave-lengths of sunlight.

Vitamin E Requirements.—Vitamin E is known as the antisterility vitamin because its absence in the diet prohibits reproduction. This vitamin was first made known by Evans and Bishop (1923) and from most recent observations it appears that when diets are deficient in vitamin E, normal ovulation is prevented or interfered with. Parkhurst (1927) and Morris and Mitchell (1928) secured results with laying hens that seemed to show that vitamin E is necessary, but much more evidence is necessary before a proper value can be attached to the importance of this vitamin in reproduction. The germ of the wheat is one of the principal sources of vitamin E and it is also found in rolled oats, whole wheat and dried alfalfa and in green leaves, such as lettuce. Card (1929*b*) found that wheat germ oil added to a mixed grain ration to the extent of 2 per cent of the ration was of no benefit.

CHAPTER XXIV

FEEDING PRINCIPLES

Although the rations fed to chickens may vary somewhat, and although the method of feeding them may also vary somewhat, nevertheless, there are certain fundamental principles that apply if feeding for any purpose is to be done most efficiently. It is not enough to know that certain nutrients are required, because some nutrients are required in larger proportions in the ration than others and there must be a proper balance among the nutrients. The feeds may differ in their energy value. Some attention must be given to such matters as the palatability of feeds and the form in which they should be fed. Then, again, a ration must be adapted to the purpose for which it is being fed and it should not have an undesirable effect on the birds nor on the product. These are matters that determine the principles of feeding.

Nutritive Ratio.—For many years the nutritive ratio was considered to be of considerable importance in the preparation of rations for the larger classes of live stock. Since protein has always been regarded as relatively the most important constituent of a ration, both from the standpoint of the part it serves in nutrition and from the standpoint of cost, the nutritive ratio is based upon the proportion of digestible carbohydrate and fat (estimated as carbohydrate) to one part of digestible crude protein. Since fat has approximately two and one-quarter times the energy value of carbohydrate, the amount of digestible fat in a feed is multiplied by 2.25, the product being added to the amount of digestible carbohydrate present, the sum being divided by the amount of digestible crude protein, illustrated thus:

$$\frac{(\text{Digestible fat} \times 2.25) + (\text{digestible carbohydrate})}{\text{Digestible crude protein}} = \text{nutritive ratio}$$

In order to compute the nutritive ratio of any feed, first ascertain from Table 47 the percentage each of fat, carbohydrate and protein contained in the feed, and then ascertain from Table 48 the coefficients of digestion of these three nutrients and determine the amount of digestible fat, digestible carbohydrate and digestible crude protein contained in the feed. Then use the values obtained as in the equation above and the final product is the nutritive ratio.

It is obvious that the greater the proportion of digestible protein to the sum of the digestible fat and carbohydrate, the narrower is the nutritive ratio. On the other hand, the smaller the proportion of digestible protein to the sum of the digestible fat and carbohydrate, the wider is the nutritive ratio. A wide nutritive ratio simply means that there is less digestible protein in proportion to the other digestible nutrients than in the case of a ration with a narrow nutritive ratio.

Minerals Not Considered.—The nutritive ratio does not take into consideration the mineral elements in the ration nor does it take cognizance of the vitamins and, therefore, can only have a limited application in the preparation of poultry rations. Moreover, as far as the digestible protein is concerned, the nutritive ratio does not take into account the fact that the various amino-acids, of which protein is composed, serve different purposes, some not being able to replace others. It is obvious, therefore, that the principle involved in the nutritive ratio can only be applied in a general sense. It is known, for instance, that young chicks require a ration relatively richer in protein than mature birds, whereas chickens being fattened require relatively little protein and thus require a ration with a somewhat wider nutritive ratio.

Energy Requirements of Birds.—The outstanding nutritive requirement of birds is that of energy for the work to be performed by the body. Since all organic nutrients serve as fuel to produce the required energy, feeds must be compared in terms of their energy value, which is expressed in terms of heat units called "calories." A calorie represents the amount of heat required to raise the temperature of one kilogram of water one degree Centigrade, which is approximately the same amount of heat required to raise four pounds of water one degree Fahrenheit.

Basal Heat Metabolism at Various Ages.—The basal heat metabolism of chickens of various ages has been studied by Mitchell and Haines (1927) and Mitchell, Card and Haines (1927). The metabolism per unit of surface is distinctly lower at hatching time than at maturity. After hatching it rises rapidly to a maximum and then decreases to the adult level, at which it remains for the greater part of life. For chicks the peak is reached at 30 to 40 days of age and the adult level at about 70 to 80 days. The basal metabolism per unit of weight decreases from the peak age to at least one year of age. It was found that the average basal heat production of 28 non-laying hens was 54.9 cal. per day per kilogram of body weight and 703 cal. per day per square meter of body surface. For 19 mature cockerels the averages were 55.7 cal. per day per kilogram of body weight and 806 cal. per day per square meter of body surface. There were also indications that the basal metabolism of the laying hen is higher than that of the non-laying hen. The basal metabolism of cockerels eventually becomes higher than that of pullets, but the age at which the difference appears has not been determined.

The average basal metabolism for a group of White Plymouth Rock chickens ranging from 72 to 363 days was for the cockerels 852 ± 12 cal. per day per square meter of surface and 805 ± 10 cal. for the pullets.

At advanced ages there is a reduction of from 6 to 12 per cent in the basal heat production for cocks and hens, respectively.

Effect of Castration.—Castration of cockerels lowers their basal metabolism, though the effect may not be immediate and may extend over a period of several months. The average maximum effect of castration in this test was a reduction of 13.5 per cent in basal metabolism.

Energy Value of Corn.—Mitchell (1926) found that 1 lb. of corn has a total gross energy content of 1,761 cal., 15 per cent of which is lost in intestinal and urinary excretions. Since 236 cal. represent the heating effect of the corn, the net energy value is 1,261 cal. per pound, which means that 72 per cent is available for performing bodily functions, tissue development and egg production. Mitchell observes that the chicken converts the energy of corn to its own use much more efficiently than the steer and probably more efficiently than the pig. In 1928 Mitchell found that ground wheat had a much higher heating value than ground corn.

Very little other work has been done to determine the energy values of different poultry feeds. Mitchell and Haines (1927), however, have estimated, from experiments conducted, that a hen on a ration composed mostly of corn and in sufficient amounts for the production of one egg per day could stand outdoor temperatures of 59° F. before requiring additional feed to keep the body warm.

Calories in the Ration.—Rosedale (1925) makes an interesting observation regarding the number of calories required in the ration.

> There should be about 350 cal. in 100 g. of food. These can be calculated by adding together the percentage of protein and carbohydrate and multiplying by 4.1, and by multiplying the percentage of fat by 9.3. These two products added together give the calorie value for 100 g. An example may illustrate this: Suppose we feed equal parts of a scratch grain mixture and a mash. The grain mixture consists of equal parts of dari and maize, while the mash is one part fish meal and four parts middlings. The percentage analysis is, 21 per cent protein; 62.5 per cent carbohydrate; 5 per cent fat; 4.95 per cent ash; 3.9 per cent fibre.
>
> $$\begin{aligned} \text{Protein} + \text{carbohydrate} &= 21 + 62.5 = 83.5 \times 4.1 = 342.35 \\ \text{Fat} &= 5.0 \times 9.3 = \underline{\ 46.5\ } \\ &\text{Making a total of } 388.85 \end{aligned}$$
>
> calories per 100 g. of food.
>
> Energy is most important, and it will, indeed, result in calamity if we allow the importance of quality in diet to mask the quantity question. Best results will never be obtained without a sufficient quantity of food being eaten and digested. Sufficient quantity cannot be digested unless the quality and balance are satisfactory. The poultry keeper must, indeed, provide ample energy.

It should be stated here that the modern practice of using liberal quantities of corn, corn meal, wheat middlings and ground oats or oatmeal in poultry rations probably supplies sufficient energy and heat for growing chicks and laying hens.

Palatability of Feeds.—The palatability of poultry feeds is of importance because the amount of feed consumed is determined to some extent at least by palatability and the results secured in growth, fattening and egg production are determined, in a measure, by the amount of feed consumed. Although from the standpoint of chemical composition, rye is much the same as wheat, it is highly probable that the substitution of rye and its products for wheat and its products (bran and middlings) would cause a decrease in egg production because rye is not palatable. On the other hand, yellow corn of good quality is a very palatable grain. The feeding of milk in some form seems to increase feed consumption, apparently because milk is so highly palatable.

Tuason and Fronda (1924) tested rough rice, cracked corn and whole sorghum and found their palatability to be in the order named. They also found that when blood meal was added to any of the mashes they tested the amount of mash consumed decreased. Rugg and Pederick (1925*a*) found that laying hens consumed larger amounts of wheat and oats than any of the following, when each was fed singly in self-feeders: corn, barley, wheat bran, oat bran, barley bran, meat meal and rape-seed meal. Kennard and Nettleton (1927) found that pullets consumed considerably more mash when it was ground coarse than when it was ground fine or when the mash contained considerable fiber. Apparently very finely ground and highly fibrous mashes are not as palatable as when coarsely ground. Newbigin and Linton (1927) tested the palatability of certain seeds to chicks and found the order to be: millet, canary seed, dari, rice, groats (hulled oats), wheat, lentils, maize (corn), peas, and linseed. It was observed that neither size of seed nor its composition had any bearing on palatability.

In poultry feeding practice the matter of palatability is largely taken care of by the liberal use of yellow corn of good quality both in the scratch and mash rations. If, however, the birds are observed to eat but little of their grains, as in the case of oats or barley of poor quality or if the mash contains an excessive amount of cottonseed meal, the ration should be changed.

The Form in Which Feed Is Supplied.—Principles of feeding determine to some extent the form in which feed should be supplied. For instance, should grains be fed whole, cracked or in the ground form? Should mashes be moistened or fed in the dry form? Is a simple ration efficient or should a complex one be fed to insure providing sufficient of the various nutrients? What is the best form in which to feed the milk products? Should the ration contain a certain amount of bulk or ballast to make it most efficient? Should a ration contain green feed to provide succulence and should a ration contain grit to aid in the grinding of the feed materials?

Whole Grain Ration.—Martin (1921–1922) compared the effect on egg production of a ration of whole grain supplemented with sour skim milk as compared with a grain and mash ration supplemented with sour skim milk and observed that mash was not necessary. In 1924, after further experiments, Martin observed that "Very satisfactory egg production can be secured without the use of dry mash when sour skim milk, liquid buttermilk, condensed buttermilk or granulated buttermilk is available as a source of protein."

All-mash Ration.—On the other hand, Kennard and Bethke (1926) secured as satisfactory egg production from "all-mash" rations as from a combination of grain and mash and were led to observe that the all-mash method of feeding has certain advantages, among which they mentioned:

1. More sanitary than when grain is fed in dirty scratching litter as often happens.
2. Less labor and skill of feeding required.
3. Enables one to feed a definite ration.

Cassel (1927) secured somewhat better results in egg production from mash rations without scratch grains than from scratch grains without mash. Kennard and Bethke (1927) confirmed their previous results which showed the superiority of the "all-mash" method of feeding growing chicks and laying hens. Carrick, Hauge and Prange (1927) went still further and found that a mash ration containing no milk, green feed or grit gave satisfactory results under laboratory conditions. Mussehl, Hill and Ackerson (1929) found that for growing chicks a simple ration composed of 43.5 per cent yellow corn meal, 22.0 per cent shorts, 22.0 per cent bran and 12.5 meat and bone scraps gave as good results as a much more complex ration, when both were supplemented with green alfalfa.

Combination Rations.—Hannas (1924) presents data showing the amounts of mash and scratch grain fed monthly in the Vineland and Bergen County, N. J., egg-laying contests, together with the monthly production from November to June, during three years. A study of these results indicates that greater yearly production, better health, and lower mortality accompanied the generous feeding of scratch grain, especially in the fall and winter. Lighter feedings of scratch grain tended to increase mash consumption, which overstimulated egg production, resulting in a dropping off in production during the summer and following fall.

Hervey (1925*b*) presents further data throwing additional light upon the importance of heavy grain feeding during the four winter months, November to February, inclusive. His conclusions are as follows:

In the winter period, egg production increased directly according to the amount of scratch grain consumed up to a maximum feeding rate of 15 pounds per 100 birds daily. There was no appreciable relationship established between scratch grain consumption and egg production for the spring and summer-fall periods. The most common scratch grain consumption was 12.0 lb., 10.7 lb. and 6.4 lb. for the winter, spring and summer-fall periods, respectively. Efficiency in scratch grain feeding was attained in winter only when a rate of 12.1 lb. per 100 birds daily was equalled or exceeded. Satisfactory production was secured with scratch grain feeding at the rate of 10.7 lb. in the spring months and the low rate of only 6.4 lb. in the last 4 months of the laying year.

Jull (1929*b*) has computed the correlations between the percentage of mash of the total grain ration consumed and egg production among certain breeds in the Storrs egg-laying contests for the years 1916, 1917 and 1919, the results being shown in Table 53.

TABLE 53.—CORRELATIONS BETWEEN EGG PRODUCTION AND PER CENT OF MASH OF TOTAL GRAIN RATION CONSUMED

Breeds	Year	Per cent of mash of total grain ration consumed	Correlation between egg production and per cent of mash of total grain ration consumed
Barred Plymouth Rocks	1916	51.17	0.076 ± 0.101
+ Rhode Island Reds	1917	49.96	0.377 ± 0.078
+ White Wyandottes	1919	58.81	0.293 ± 0.086
	3 yr.	53.26	0.106 ± 0.054
White Leghorns	1916	45.25	0.479 ± 0.082
White Leghorns	1917	46.53	0.608 ± 0.072
White Leghorns	1919	54.99	0.404 ± 0.086
	3 yr.	49.18	0.356 ± 0.054

All of the correlations are positive in character and six out of the eight show significance, since in each case the correlation is more than three times its probable error. This means that when scratch grain and mash comprise the ration, the more mash the birds consume the more eggs they are likely to lay, apparently because the animal protein intake is increased as the mash consumption increases.

Commercial Rations.—Since the feeding of mash rations as compared with scratch rations and scratch and mash rations has been on the increase, the important problem arises as to whether it is preferable to use a mash prepared on the premises or a commercial mash prepared by one of the milling companies. The problem is not one of price or labor alone for Rolf (1927) points out that different samples, even as large as car loads, of the various grain products and protein supplements frequently vary considerably in their composition. He shows that a farmer might make up two mash mixtures varying in their protein content as much as from 15.89 to 28.76 per cent. In actual practice, however, such marked variation would perchance occur very infrequently for the simple reason that if a given sample of middlings ran below the average in protein content, the sample of bran, corn meal, oatmeal or meat and bone scraps might run above the average and thus all the samples used in the same mixture would tend to provide the desired average.

At the same time, Rolf's suggestion is worthy of consideration because the milling companies, with their excellent grinding and mixing facilities, can turn out a more uniform product than the average farmer could hope to mix at home. The thoroughness with which a mash is mixed is of considerable importance. Again, on most commercial poultry plants and on many farms where a considerable number of poultry is kept, the labor problem practically prohibits the mixing at home of the relatively large quantities of mash required. The fact should not be overlooked that the feed or milling companies are able to add minerals and vitamins to the commercial mashes they prepare whereas it is sometimes difficult for the average farmer to secure the proper kind of minerals and vitamins to supplement his home-prepared mash.

Moist Mashes.—A few years ago the feeding of moist mashes was a popular practice, but with the rapid development of the poultry industry and the relative increase in the size of commercial and farm flocks, the feeding of wet mashes has decreased. Moreover, with the improvement in the quality of prepared mashes which has taken place during the last few years and with the possibility of incorporating in dry mashes dried milk products, there would appear to be less need to feed moist mashes, except to secure an increased consumption of grain in order that the body weight of layers may be maintained, thus avoiding a summer slump in egg production.

The moist-mash and dry-mash methods of feeding growing chicks were tested by Mairs (1908) and Lewis (1911*b*). Mairs observed that moist mash gave better growth than dry mash up to the time the chicks weighed about one pound each but after that the situation was reversed. Lewis found that moist-mash feeding induced greater gains in weight but at a cost of higher mortality.

Owen-John (1923) secured better egg production from pens fed dry mash than from pens fed moist mash. Rugg and Pederick (1925*b*), however, secured better results from moist-mash feeding than from dry-mash feeding. Undoubtedly the amount of labor involved in feeding dry or moist mashes is an important factor in determining which should be fed.

Milk.—Milk products are prepared for poultry feeding purposes in five different forms and it is a question as to which form is the most efficient one to use. Card (1926) compared sour skim milk, fresh buttermilk, condensed buttermilk and dried buttermilk. He did not test dried skim milk. The results he secured led him to suggest that "it appears that the question of whether to use sour skim milk, fresh buttermilk, condensed buttermilk, or dried buttermilk, will depend not upon a difference in nutritive value but upon such factors as: (1) Convenience in feeding: (2) The importance, in certain instances, of maintaining the protein intake at a constant percentage of the total ration: and (3) The availability and cost of the various forms of milk." Where sour skim milk or buttermilk are not readily available, dried skim milk or dried buttermilk could be incorporated in the dry mash to good advantage.

Need For Bulk.—The question as to whether the ration should contain a certain amount of bulk or ballast has received some consideration. The results secured by Kennard and Nettleton (1927), noted previously, suggest that a certain amount of bulk is desirable for they observed that pullets consumed more of a mixture of coarsely ground grains than the same mixture of finely ground grains. Kalugin (1878) claimed that crude fiber as well as crude protein are more fully digested by chickens when sand and charcoal are added. On the other hand, Weiske (1878), von Knieriem (1900), Tangl (1908), Katayama (1924) and Fraps (1928), as well as others, have observed that crude fiber is not digested to any extent by the chicken. Katayama showed that quartz sand had no specific effect on the digestion of crude fiber and he observed that, since chickens often prefer materials rich in crude fiber, it is used primarily as a ballast for the organs of digestion.

Results secured by some of the early workers in conducting feeding tests—Osborne and Mendel (1918) and Hart, Halpin and Steenbock (1920)—led them to believe that growing chicks require indigestible ballast in their rations. Later work, however—Hart, Steenbock, Halpin and Johnson (1924) and Payne (1926)—seems to show that bulk or ballast has been overemphasized. Where scratch grains are fed in combination with mashes, it is probable that the problem of bulk is sufficiently taken care of, but, where mashes only are fed, it is perhaps best to give some bulky feed as a supplement.

Green Feeds Necessary.—Some form of green feed is probably the most efficient way to supply the necessary bulk to the ration. Many green feeds supply protein, minerals and vitamins and in addition frequently provide succulence and bulk, the latter feature being important from the standpoint of separating the finer particles of grain in order to make them more readily acted upon by the digestive juices in the alimentary tract. Mussehl, Calvin, Halbersleben and Sandstedt (1921) suggest that the addition of greens to the ration improves its physical condition and increases consumption. Atwood (1922) urges the liberal use of green feeds during winter confinement.

Bethke, Kennard and Kick (1925) observe that the feeding of green plant tissue to chicks has a beneficial effect on growth and Kennard and Nettleton (1926) found that high quality green, leafy alfalfa, red clover, and soy-bean hay may be substituted for succulent green feeds during the fall and winter months. In 1928 the Ohio Agricultural Experiment Station found that high quality alfalfa hay, chopped in half-inch lengths, and 5 or 10 per cent by weight of alfalfa leaf meal were excellent additions to the basal ration.

Is Grit Necessary?—The feeding of grit to provide bulk or ballast to the ration has been a subject of much discussion. Wheeler (1903) and Jull (1915*b*) found from experiments that the addition of grit was of considerable value in feeding chicks in confinement. On the other hand, Buckner, Martin and Peter (1923) observe that "The absence of grit from the diet of hens in confinement during the first eight months of their laying period does not affect their egg production nor their physical condition." The same authors (1926*b*) found that grit is not essential to the growth of chicks up to eight months of age. Bethke and Kennard (1926*b*), from a series of experiments with chicks, came to the conclusion that grit is of no benefit for grinding purposes. Mangold (1927) observed that the presence of sand or small stones allows hens to derive more benefit from their feed when this is composed of grain.

It would seem, therefore, that when a mash only is fed, the presence of grit may serve no particular purpose, except possibly to provide bulk, but that when whole or cracked grain constitutes part of the ration, the feeding of grit may facilitate the breaking down of the food particles and thus aid in the more rapid digestion of the nutrients.

The Effect of Feed on the Birds.—The feed must not only be adapted to the purpose intended, whether it be to promote growth, to develop tissue and fat in fattening or to produce eggs, but it must also be adapted to keeping the birds in the best condition in order to produce the desired results. An excessive amount of carbohydrate and fat in the diet of laying hens kept in confinement may induce excessive fatness in the birds, retard laying, and ultimately produce fatty degeneration of the liver. On the other hand, an excessive amount of protein in the ration for growing chicks may induce too early sexual maturity. Kionka (1900) observed that an excessive meat diet for hens led to the development of a condition similar to gout in man. Deficiencies in minerals or a lack of proper balance between the calcium and phosphorus content of the ration frequently results in the development of leg weakness. This problem has been discussed previously, under the section of mineral requirements in Chap. XXIII.

The various dietary diseases due to the lack of one or more of the vitamins have also been discussed previously, under the section on vitamin requirements in Chap. XXIII. A few more observations serve to illustrate the effect of feeds on the birds. Dutcher and Wilkins (1921) found that when cockerels were fed solely on polished rice the testes decreased in size but feeding fresh alfalfa tended to regenerate them. Souba (1923*b*) not only found that the testes decreased when vitamin B was deficient but also observed a decrease in the size of the heart, liver, kidneys, pancreas and thyroid gland. Penquite (1926) found that cockerels deprived of certain vitamins produced smaller spermatozoa than cockerels receiving normal rations.

Anderson and Kulp (1922) observed that continued lack of vitamin B caused a serious impairment of the digestive functions. Beach (1924) described "a nutritional disease resembling roup" due to a deficiency of vitamin A. Similar observations were made by the Kansas Agricultural Experiment Station (1928) where it was reported that birds on vitamin-A deficient diets developed lesions about the eye, in the throat and nose and showed a deposition of urates throughout the body. Kříženecký and Petrov (1926) found that vitamin B is not only necessary for feather growth but is essential in the diet to provide the stimulus for feather development.

Effect of Feed on the Product.—Just as feed may affect the birds so may it also affect the quality, condition or other factor of eggs and poultry meat.

Size of Egg.—The various factors affecting the size of eggs laid have been studied by Atwood (1914, 1917*b*, 1926) and, among other things, he found that scanty feeding reduced the size of eggs; improperly balanced rations reduced the size of eggs; the eggs and yolk from hens fed wheat were somewhat heavier than the eggs and yolk from hens fed corn; a winter ration consisting of whole grain reduced the weight of the eggs about 12 per cent as compared with a winter ration of scratch grain and mash; and a considerable amount of animal protein in the ration tended to weaken the vitelline membrane of the yolk. Parkhurst (1924, 1927–1928) observed that laying hens receiving no protein-supplement feeds laid smaller eggs than hens fed rations to which were added animal and vegetable protein supplements and that sour skim milk was superior to any other supplement to the ration in affecting egg size favorably.

Color of Yolk.—It has long since been established that yellow corn produces yolks darker yellow in color than white corn. Palmer (1915) demonstrated that the yellow corn contains a pigment called "xanthophyll" and that it is xanthophyll that gives the rich yellow color to the yolk. Alfalfa and clover also tend to produce dark yellow yolks. Payne (1925) observed that two weeds belonging to the mustard family, penny-cress and shepherd's purse, caused the production of eggs having both the white and yolk tinted with green. Waste pimiento pepper has been shown by Morgan and Woodruff (1927) to produce dark yellow yolks.

Parker, Gossman and Lippincott (1926) found that birds receiving white corn with no green feed produced eggs with very pale yolks, and that brighter colored yolks resulted when the birds received yellow corn, green feed, or both. Head lettuce and sprouted oats had little more effect than when no green feed was added. Miss Parker (1927), however, found no definite seasonal trend in yolk color. Parker, Gossman and Lippincott (1926) observed individual differences among hens in respect to the color of the yolk produced and Platt (1929*b*) observed individual differences among hens in respect to the firmness of the white of the egg.

Flavor of Eggs.—Nieber (1925) observed that hens fed grain treated with corbin laid eggs that had a sharp tar-like taste when boiled. Lippincott (1927) reports that "onions, rape, turnips and fresh fat fish, if fed in excess, impart a strong flavor to eggs."

Vitamin Content of Eggs.—Bethke, Kennard and Sassaman (1927) found that the vitamin A content of yolks was increased considerably by feeding hens rations rich in vitamin A. That the vitamin D of eggs is affected by the amount of vitamin D in the ration is reported on page 358.

Chemical Composition of Eggs.—Pollard and Carr (1924) found that when pigeons were fed on diets restricted to a single kind of grain supplemented with grit, oyster shell, ground bone, salt, charcoal, and tap water, the eggs produced varied greatly in chemical composition, depending upon the kind of grain used. The grains fed separately were: barley, corn, oats, wheat, rye, kafir, hemp, popcorn, sunflower seed, soy-bean seed, field peas and buckwheat. Eggs produced from the kafir diet had the highest total nitrogen content while eggs produced from the diet of oats had the lowest total nitrogen content. The character of the proteins in eggs from the different grains varied considerably.

Keeping Quality of Yolks.—Not only may feed affect the size, color, flavor, vitamin A content and composition of eggs, but Sherwood (1928) has shown that rations containing 10 per cent or more of 43 per cent protein cottonseed meal caused the production of eggs the yolks of which become badly discolored when kept in cold storage.

Bacterial Content of Egg.—Bushnell and Maures (1914) observed that hens fed a moist mash laid eggs having a higher bacterial infection than eggs from hens fed dry mash.

Composition of Flesh.—The results of fattening experiments carried on by officials of the U. S. Department of Agriculture, under the supervision of McAleer and Pennington (1922) show that fattening changes the chemical composition of the bird. For instance, the per cent of protein in the meat of unfattened broilers was 21.08 whereas in fattened broilers it was 19.97. Other changes were observed in other parts of the bodies of various classes of fattened as compared with unfattened chickens.

Flavor of Flesh.—It is well known that wild ducks when cooked sometimes have a fishy flavor, imparted apparently by a heavy consumption of fish. It is not surprising, therefore, to find that under certain conditions the feeding of cod-liver oil to chickens imparts a fishy flavor. Carrick and Hauge (1926) found that chickens fed a ration containing 4 per cent cod-liver oil had a distinct fishy flavor although the feeding of the cod-liver oil had been discontinued prior to the time of killing. Chickens fed rations containing 2 per cent of cod-liver oil which was withdrawn two weeks prior to killing did not have a fishy flavor.

CHAPTER XXV

FEEDING PRACTICE

In its natural habitat the wild fowl gets its living from the green parts of plants, seeds, grains, insects, worms, and certain minerals from the earth. Abundant variety is ensured, thus providing an adequate supply of carbohydrates and fat, protein and minerals and, since the wild fowl lives an outdoor life, sunshine provides for the proper assimilation of bone-forming materials. The chicks are hatched during the spring of the year, the normal reproductive season, when many other forms of life are "coming into being," so that the chicks are provided with all of the elements of plant and animal life required for growth. The adult birds, having laid a sufficient number of eggs to reproduce their kind, enjoy a prolonged holiday so far as egg production is concerned and have only to prey upon sufficient plant and animal life to "keep their bodies going" and to be on the alert lest they themselves are preyed upon by larger animals. Except for their natural enemies, life must be pleasant. Food is usually abundant, the living and sleeping quarters are sanitary, growth proceeds leisurely and a few eggs are produced in due season.

What a striking contrast is produced under modern conditions of poultry raising. Domestic breeds of chickens raised for egg and meat production are larger than the wild fowl; chicks are hatched at all times of the year and they are often reared in large flocks on very limited range or in confinement; their quarters are frequently unsanitary; they are expected to grow rapidly; laying hens are fed to lay as many eggs as possible. Though the nature of the feed required by the modern domestic chicken is essentially the same as that of the wild chicken, the amounts required are much greater, and, when chicks are raised in confinement and layers are kept in confinement, particular attention must be paid to the balancing of the ration with minerals and vitamins.

The grains and their by-products constitute by far the major portion of rations for all classes of chickens. But no single grain is a complete feed and even a mixture of cereals is deficient in respect to the amount and quality of protein, minerals and vitamins, especially for birds that do not have access to sunlight. All grains are deficient in water and sometimes a mixture of ground grains lacks sufficient bulk.

In order to provide supplements to supply the various deficiencies of the grains, at least a part of the ration should be fed in the form of mash in order that animal or vegetable protein, certain minerals and sometimes vitamins can be added to it. This does not mean that the ration needs to be an extremely complex one, in fact, mash feeding enables a simple ration to be fed and the method of feeding is very greatly simplified.

FEEDING THE CHICKS

The main object sought in feeding chicks is to secure a good rate of growth with as little mortality as possible. Although several different rations have been used apparently with equal success, three things must always be kept in mind: (1) The protein supplements, whether of plant or animal origin, should be of the highest quality; (2) there must be an adequate supply of the right kind of minerals; (3) direct sunlight or vitamin D must be accessible to enable the chicks to make use of the minerals for the purpose of bone development as well as to provide for best conditions of growth.

Chick Rations.—A number of chick rations are given below that have been tested experimentally and have given satisfactory results in practice:

The Wisconsin Chick Ration

(Hart, Steenbock, Halpin and Johnson, 1924)

	Parts by Weight
Yellow corn meal	45
Wheat middlings	15
Wheat bran	15
Dried milk	12
Meat scraps or meat and bone meal	6
Alfalfa leaf or high grade green alfalfa leaf meal	3
Calcium carbonate grit	3
Salt	1
	100

This ration is fed as a dry mash, the skim milk being given instead of water. No scratch grain nor green feed is provided but sunlight is necessary. If sour skim milk is not available, 30 parts of dried skim milk should be added to the above ration. Halpin (1929) states that the ration given above has been suggested largely in a form to illustrate the fundamental principles involved in the preparation of chick rations. He says that at the Wisconsin Experiment Station the following ration has been used quite successfully: yellow corn meal 45, pure wheat bran 15, pure wheat middlings 15, dried milk 15, meat scraps 7, alfalfa leaf meal 3, and salt 1, all parts by weight. Water is given as drink, chick-size oyster shell or high calcium limestone is given in a self-feeding hopper and chick-size raw bone should also be given in a self-feeding hopper.

The Ohio Chick Ration

(Kennard and Bethke, 1927*a*)

	Parts by Weight
Coarsely ground yellow cornmeal	70
Winter wheat middlings or ground wheat	20
Meat scraps (containing 50 per cent protein)	5
Bone meal (chick size)	4
Salt	1

The authors state that milk in some form should be fed only during the brooding season. Skim milk or condensed buttermilk added to the water at the rate of 1 to 2 lb. to each gallon of water may be given as a drink, or dried buttermilk or dried skim milk may be added to the above ration sufficient to make from 10 to 15 per cent of the ration. Oyster shell should be available at all times or, if the chicks are confined, there should be added to the ration chick-size oyster shell or limestone grit to make 3 per cent of the ration. This addition of mineral feed is not necessary, however, if from 1 to 2 per cent of the ration consists of cod-liver oil. Only cod-liver oils that have been tested, especially for vitamin D, should be fed. In adding cod-liver oil to the ration, first determine the proper amount of oil to add to the amount of feed being mixed, then mix the oil with a small amount of feed, stirring the grain while pouring the oil on it, and then mix this mash with the larger amount and mix very thoroughly. The authors suggest that if the chicks do not have access to blue grass, clover or alfalfa range, they should be supplied with green clover or green alfalfa or clover or alfalfa hay cut into ¼ to ½-in. lengths.

The Indiana Chick Ration

(Carrick, Hauge and Prange, 1927)

	Parts by Weight
Yellow corn meal	50
Wheat middlings	15
Wheat bran	15
Meat scraps (50 per cent protein)	19
Salt	1

The authors state that water is given as drink and that the chicks should have sunlight for an hour or more daily, or cod-liver oil amounting to from 2 to 3 per cent of the ration should be added. They also state that when 6 per cent of dried buttermilk was used to replace 5 per cent of meat scraps and 1 per cent of corn, there was more rapid growth.

The following chick ration differs from the three preceding in that it provides a scratch ration in addition to the mash ration.

THE KANSAS CHICK RATION

(Payne, 1926)

	Parts by Weight
Scratch Ration:	
Cracked yellow corn	60
Cracked wheat	20
Pinhead oats or cracked kafir	20
Mash Ration:	
Wheat bran	30
Wheat shorts	30
Yellow corn meal	25
Meat scraps	10
Bone meal	3
Crushed oyster shell or ground limestone	1
Salt	1

Chick Feeding Methods.—The customary practice of withholding feed from the chicks for the first 60 to 72 hr. is not necessary, according to the latest observations. As early as 1922, Malarski advised feeding chicks as soon as possible after hatching. Roberts (1928) conducted experiments the results of which led him to suggest that chicks may be fed as soon as they are fluffed out without adversely influencing growth or mortality. He also adds, however, that withholding feed for 48 hr. gave just as satisfactory results as feeding earlier.

The reason for the advice against feeding chicks before they are from 60 to 72 hr. old was because of the supposition that the unassimilated yolk in the chick at hatching time served to nourish it for 2 or 3 days and, if the chicks were fed during that time bowel trouble would probably result. That such is not the case, however, has been shown by Schilling and Bleecker (1928), who found that the level of intake of feed did not influence the rate of the disappearance of yolk. Chicks making the best growth neither assimilated their reserve yolk more rapidly nor more slowly than other chicks.

Parker (1929) reports that Virchow (1891) made observations on the rate of yolk assimilation and she herself carried out a number of unique experiments on subjecting chicks to different kinds of treatment in respect to their effects on the assimilation of yolk and the growth of the chicks. Although Miss Parker found "a significant positive correlation between day-old body weight and the weight of unassimilated yolk, up to and including the age of 5 days" she also found that "a variety of early handicaps including poisons, starvation, and high and low termperatures, failed to alter markedly the course of yolk absorption in baby chicks."

Heywang and Jull (1930) found that feeding the chicks at 24 and 48 hr. after hatching seemed to increase the rate of yolk assimilation. It is apparent, therefore, that chicks may be fed as early as 24 hr. after hatching without in any way affecting the rate of absorption of the reserve yolk.

The First Few Days.—The mash rations given previously are usually fed on flat boards with small strips around the edges and, then, as soon as the chicks are able to eat out of self-feeding hoppers, the mash is placed in them. While the boards are being used, however, great care should be taken never to allow the mash to get dirty. For the first few days the mash should be sprinkled on the boards about five times daily, giving enough each time to keep the chicks busy for about fifteen minutes, after which the boards should be taken up and cleaned thoroughly and hung up until next feeding time. The hoppers should never be allowed to become empty nor clogged and at the same time the hoppers should avoid waste as much as possible.

Scratch Grain.—When scratch grains constitute a part of the ration they should be fed from three to five times daily, only a little at a time. The scratch mixture may be scattered in the litter or it may be fed in self-feeding hoppers as soon as the chicks are able to eat from them. If the scratch mixture is fed in the litter, great care should be taken to keep the litter clean at all times. Of course, the litter should always be kept clean, but it is especially important in the case of feeding scratch mixtures. As the chicks grow older the scratch mixture may be fed twice a day, morning and evening, unless it is fed in self-feeding hoppers. At each feeding of the scratch mixture, only enough should be given so that all of the grain will be picked up in about fifteen minutes otherwise some may be left to become covered with disease germs.

Milk Valuable.—Water or milk in some form should be given as a drink as soon as the chicks are placed in the brooder house. With many rations better growth is usually secured if sour skim milk is given as a drink instead of water. Giving sour skim milk instead of water to drink or using abundant supplies of dried skim milk or buttermilk in mash rations tends to prevent or overcome the ravages of the disease called "coccidiosis." Beach and Davis (1925*a*, 1925*b*) found that feeding chicks for the first two weeks wholly on mash containing 20 per cent lactose (milk sugar) or 40 per cent dried skim milk proved to be an excellent control measure for coccidiosis. Great care should be taken to keep the drinking fountains clean at all times.

Green Feed Important.—Green feed of some kind makes a good supplement to any ration, particularly for chicks raised in confinement. For this purpose green clover, green alfalfa, lawn clippings, or well-cured clover or alfalfa hay cut into ¼ to ½ in. lengths, may be fed.

If oyster shell is not contained in the mash ration then it should be fed in self-feeding hoppers.

Vitamin D For Confined Chicks.—Finally, if the chicks are given free range they usually get abundance of sunlight so that leg weakness should never be encountered. Where confinement rearing is practiced, so that the chicks do not have access to sunlight, then vitamin D should be suplied. Perhaps the simplest way of doing this is to add from 1 to 2 per cent of tested cod-liver oil to the ration, mixing it with the mash as described on page 377.

FEEDING THE YOUNG PULLETS

Since the principal object in hatching chicks each year is to raise a sufficient number of pullets to replace the old hens which have been eliminated from the flock, it is obvious that the feeding of the pullets during the growing period should receive first consideration. The cockerels should be separated from the pullets at an early age, a problem discussed on page 239.

It has been pointed out previously that, as the chicks develop, their requirements for protein decrease relatively and it has also been observed that too much protein in the ration for pullets throughout the entire growing season tends to bring them into laying condition .too early. The best annual records of egg production and the greatest profit per bird per year are usually made by pullets that commence laying in October. This is because egg prices are higher during the late summer, fall and early winter months than at any other time of the year. It is possible, of course, to hatch chicks as early as December and January and have them come into laying in July and August, when egg prices are on the increase. At the same time, great care must be taken to prevent such early hatched pullets from going into a full neck or body molt, thus retarding production. This can be prevented to a considerable extent, however, by the proper use of artificial lights in the laying house, as explained later in this chapter.

Regardless of how early the chicks are hatched, it is well to reduce the amount of protein in the mashes given previously at about the time the cockerels are separated from the pullets. In the case of late-hatched bred-to-lay pullets and pullets of some strains bred for exhibition purposes, this might not be advisable because it might retard production until December or January. With other pullets, the following practice is advisable. At the time of the separation of the sexes, remove all or most of the animal protein from the ration and do not give skim milk to drink. Holst and Newlon (1927) recommend, in the case of scratch and mash feeding, feeding approximately two-thirds grain and one-third mash from about fourteen weeks to the time the pullets are put in the laying house. The consumption of mash can be controlled by placing limited amounts in the hopper every day or two or three times every week. Attempts to regulate growth by feeding practice should be carried out with pullets of the same age and size. More careful feeding is required but the pullets are prevented from laying prematurely and are given a chance to develop physically and to put on fat, which is very necessary if they are to be kept in good laying condition throughout the fall and winter months. Young pullets should have access to clean range if at all possible or they should be fed green feed and vitamin D.

FEEDING THE LAYERS

Maximum egg production is largely controlled by the breeding of the stock as well as by the kinds of feeds given and the method of feeding. Stock that has been bred for egg production is essential and it must be well managed, including proper housing and good feeding. Breeding and housing problems are discussed in other chapters and, as this chapter deals exclusively with feeding problems, it will be assumed that other conditions are such as to produce best results.

Prices of Feed and Eggs.—The more important problems to be kept in mind in feeding the layers have been briefly summarized by Jull and Lee (1927) and the following introductory remarks to this section are adopted from their observations, with changes and additions. Since the major portion of the total poultry receipts on farms and commercial poultry plants is obtained from eggs, it is very important in feeding laying hens to get the largest possible returns in egg production at the least possible expense. The cost of the feed consumed and the price of eggs, therefore, are the two most important factors determining profits in egg production. The farmer or poultryman cannot very well control prices, but he can control egg production, at least to a considerable extent.

Egg prices are highest during the fall and early winter months, and every poultry raiser should realize that good egg production during this period pays well. Fall and early winter production is the keynote to greatest profits. Pullets should commence laying in October or early in November.

The usual advance in the price of eggs, particularly fresh eggs, during the fall of the year, is due largely to natural causes. The molting of the yearling stock shuts out this source of production, leaving pullets practically as the only source of fresh eggs at that time. Pullets, particularly of the heavier breeds, should not commence laying before they are about 7 months old, although Leghorns are usually well developed for laying at about 6 months of age.

Undeveloped and immature pullets are very prevalent in many farm flocks late in the fall and early in winter and this tends to increase the scarcity of fresh eggs when prices are naturally high. All pullets should be put into their laying pens about the first of September in order to accustom them to their new place by the time they are ready to lay. Well-matured pullets of good health and vitality should be the first consideration in building up a laying flock.

Feed the Most Important Cost Factor.—Among the several factors affecting the cost of producing eggs, feed is the most important, since it normally represents from one-half to two-thirds of the total cost of egg production. The kinds of feeds given and the method of feeding are, therefore, very important matters. At the same time, it cannot be said that there is any best method of feeding the laying stock, because flock averages of 150 eggs per bird have been obtained when different rations and different methods of feeding have been used. On the other hand, there are general principles which apply in feeding practice, and it is possible to suggest rations which should give satisfactory results under average conditions.

Rations For Layers.—The following rations are given as being typical rations for layers that have given success. Some of the rations employ scratch grains and mash while others are mash rations exclusively.

THE MISSOURI LAYING RATION

(Kempster, 1925*b*)

	Parts by Weight
Scratch Ration:	
Shelled or cracked yellow corn	10
Oats, wheat, kafir or milo	5
Mash Ration:	
Wheat bran	2
Wheat shorts	2
Yellow corn meal	2
Meat scraps or tankage	1½

Kempster suggests that the parts by weight mentioned above are the proper amounts in pounds of the feeds for a daily ration for 100 laying hens. Grit, oyster shell, or finely crushed soft limestone rock and fresh water should be available at all times. Green feed should be provided regularly.

THE WASHINGTON STATE LAYING RATION

(Carver and Cassel, 1925)

	Parts by Weight
Scratch Ration:	
Wheat	200
Cracked yellow corn	100
Oats	100
Mash Ration:	
Wheat bran	200
Wheat middlings	100
Ground yellow corn	100
Meat meal (60 per cent protein)	75
Fine bone meal	25
Salt	5

The authors state that grit, oyster shell and charcoal should be fed in hoppers. Green feed is regarded as a very important supplement to the above ration and is provided by feeding fresh green feed, such as green alfalfa, kale, lettuce or sprouted oats, when it is available, and in the winter months well-cured alfalfa leaves and blossoms.

The Ohio Laying Rations

(Kennard and Bethke, 1926–1927)

	Parts by Weight
Coarsely ground yellow corn	40
Coarsely ground wheat	20
Finely ground oats	20
Winter wheat middlings or shorts	10
Meat scraps (50 per cent protein)	10
Granulated bone meal	2
Salt	½

An alternative all-mash laying ration is also suggested:

	Parts by Weight
Coarsely ground yellow corn	70
Winter wheat middlings or shorts	20
Meat scraps (50 per cent protein)	10
Granulated bone meal	2
Salt	½

The authors state that either of these mashes gives satisfactory results but that milk in some form proves a valuable addition. Also, green feed and oyster shell should be fed.

Laying Ration with Vegetable Protein Supplement

(Holst and Newlon, 1927)

		Parts by Weight
Scratch Ration:		
Corn or milo		116
Wheat or kafir		116
Barley or oats		116
Mash Ration:		
Yellow corn or milo	ground together	80
Wheat or kafir		80
Barley or oats		80
Fish or meat scraps (50 per cent protein)		15
Soy-bean meal (or peanut meal)		75
Mineral mixture (60 per cent steamed bone meal and 40 per cent ground limestone)		17
Finely ground salt		1¾

The authors state that vitamin A and oyster shell should be fed in addition to the above ration.

Commercial Laying Rations.—Instead of using any of the rations suggested above, a good commercial mixture may be used. There are numerous scratch and mash mixtures prepared by feed and milling companies and the use of some of these mixtures saves a great deal of labor as compared with mixing mashes on the premises. Moreover, a more thorough mixture is usually secured. Other advantages in using commercial mixtures are discussed on page 369.

Method of Feeding the Layers.—From the time the pullets are placed in the laying house they should be so fed and managed that egg production will gradually increase until it reaches about 65 per cent production daily, which means that for every 100 birds 65 eggs are laid daily. If egg production is stimulated excessively, the layers may lose weight and go into a molt. On the other hand, if there is not sufficient protein in the ration, the birds may get too fat and egg production will be retarded.

Maintaining Body Weight.—Platt (1927) presents data that show that White Leghorn pullets should attain a body weight of approximately 4 lb. each before the winter of their first laying year. If this weight is allowed to decrease it is accompanied by a decrease in egg production. He found that Leghorns weighing from 4 to 4.5 lb. during the pullet year may be expected to produce the greatest number of eggs and that any weight in excess of this is detrimental to maximum production.

Avoiding the Spring Slump.—It has also been determined that egg production is liable to drop immediately after the normal season of heavy production in the spring of the year. Such a situation often develops because the birds do not consume sufficient quantities of feed, and this can be remedied by feeding a moist mash in V-shaped troughs, dry mash being used moistened with milk, or the amount of scratch grain should be increased.

Amount of Feed Consumed—Usually birds bred for high egg production consume slightly more feed than less well-bred birds of the same size. Leghorns laying an average of approximately 150 eggs per bird consume from 70 to 85 lb. of grain feed per year, and general-purpose breeds with the same production consume about 80 to 95 lb. per year. Leghorns and similar breeds require approximately 10 lb. of scratch grain and 10 lb. of mash daily, while Plymouth Rocks and similar breeds require 12 lb. each of scratch grain and mash daily per 100 birds. From this it is apparent that when a scratch ration is fed in addition to the mash ration, the former should be fed so that the birds will consume as much of it as they do of the mash which is before them at all times.

Judging the Condition of the Bird.—The feeding of a mash ration without a scratch ration saves labor, but also means that the feeder has less contact with his birds. Whether an all-mash ration or a combination of scratch grain and mash be fed, it is most important that the layers be watched closely and occasionally examined by hand when they are on the roost at night, if trap nesting is not practiced, to see that they are not getting too thin or too fat.

Method of Feeding.—In feeding a scratch ration give a light feeding in the litter or in open hoppers in the morning and a heavy feeding at night so that the layers will go to roost with their crops full.

Green feed of some kind should be fed daily and oyster shell and water should always be accessible. Kennard (1927) advises giving warm water during the winter months in latitudes where water naturally freezes. Sour skim milk should be given as a drink if it is available and may replace some of the meat and bone scraps in some of the rations. The drinking vessels should be kept in a sanitary condition at all times, otherwise they may become sources for the spread of disease. If direct sunlight is not accessible in the laying house, it may be advisable to add cod-liver oil to amount to 2 per cent of the mash ration. No condiments of any kind are necessary and, in fact, may be detrimental to good egg production.

The Use of Artificial Lights.—In many parts of the country the number of hours of daylight during the late fall and early winter months is much less than during the summer months. The laying hen's working day is thus reduced, feed consumption is not as great as it otherwise would be and egg production is thus retarded somewhat.

Many years ago poultry keepers in Spain hung oil lanterns in their poultry houses to lengthen the winter days in order that feed consumption and egg production might be increased. Lippincott (1927) observes that "The use of lights to lengthen the feeding day appears to have been first practised by Dr. E. C. Waldorf in 1895. Halpin secured favorable results from the experimental use of lights at Michigan Agricultural College as early as 1906." Bent (1909) was an early advocate of the use of artificial lights at night and fed his own flock at 9 p.m. a hot wet mash, properly seasoned, using lamps to provide light.

Electric Lighting.—The most practical way of lighting laying houses artificially is by the use of electricity. Electric-light bulbs are suspended from the roof of the laying pen in such a manner as to give the maximum amount of light on the floor and some light on the roosts, otherwise the birds will not leave the roosts and cannot get back to them when the light is turned off at night. One 40-watt bulb should be used for each 200 sq. ft. of floor space, the bulbs being placed not more than 10 ft. apart. The proper height of the bulb depends upon the depth of the house and the height of the roosts. The height required to give the proper amount of lighting is shown in Fig. 156. Reflectors 4 in. in depth and 16 in. in diameter, as shown in Fig. 157, should be used to disperse the light properly.

Dimming System for Night Lighting.—In case lights are used at night, a dimming system must be provided, using one set of bulbs of very low power on a two-circuit system. The bright lights are turned off first, leaving the dim ones on for about fifteen minutes to enable the birds to go to roost. Automatic switches to turn the lights on and off are on the market or a home-made alarm-clock switch may be devised.

Four Methods of Lighting.—Any one of four different methods of using the lights may be employed: (1) using the lights in the morning only, (2) in the evening only, (3) in the morning and evening, (4) at night. Using lights in the morning only has the advantage of not requiring a dimming system and, moreover, the birds do not have to be attended to during the night hours. Sufficient feed may be given the evening

Fig. 156.—Artificial lighting, when properly used, in the northern sections of the country, means increased egg production during the fall and winter months. (*Photograph by Reliable Poultry Journal Publishing Company.*)

Fig. 157.—The use of artificial lights in stimulating fall and winter egg production is of particular value in the northern sections of the country. A dimming system allows the layers to retire in comfort. (*Photograph by Reliable Poultry Journal Publishing Company.*)

before for that evening's feed and for the next morning. Using the lights in the evening only insures the birds getting plenty to eat before going to roost. Using the lights morning and evening gives the birds uniform working days throughout the winter. Using lights at 9 p.m. at night serves to break the long nights from supper to breakfast.

Results from Lighting.—A number of observations regarding results secured from the use of lights have been made and a few of them are given here. Lewis (1920) observed that pullets without lights gave an average profit per bird, for a period of 9 months, of $3.30 as against $5.07 for pullets given morning lights and $5.48 for pullets given a feed between 9 and 10 p.m. Allen (1926) secured data on 286 flocks and published results based on the average number of eggs per bird during the period that lights were used. The average production per bird was 67.1 eggs for the flocks using no lights and 75.8 eggs where lights were used. When lights were supplied for one hour late in the evening in the so-called "evening lunch" system, the production averaged 71.9 eggs as compared with 77.2 eggs when the day was lengthened to 12 hr. by morning lights, and 75.9 eggs when the length of day was made similar by the use of both morning and evening lights.

Tomhave and Mumford (1927) drew the following conclusions from an experiment they conducted:

> Artificial illumination aids materially in increasing winter egg production. Artificial illumination aids in making the production curve approach more nearly the price curve during the winter months. Lights were of no value, after March 1st, in stimulating production. When lights were no longer to be used, their discontinuance must be gradual to avoid disaster to egg production. Early hatched pullets, subject to a fall molt, may be safely carried over this period by the use of artificial lights. Eggs can be produced more economically under artificial illumination during the winter months than under natural conditions. Pullets in the lighted pen returned a greater profit over feed than the pullets in the unlighted pen. The use of artificial lights is not detrimental to the health of the birds under a 12- to 14-hr. day. The early morning scratch grain may be omitted provided the morning allowance is fed in the afternoon.

Parkhurst (1927–1928*b*) used late-hatched pullets to compare the results in providing lights to give an average 12-hr. day with no lights, and found that the lighted pen consumed more feed per bird, laid more eggs per bird and gave greater profits. Also the body weight of the birds in the lighted pen became greater than that of the birds in the unlighted pen.

Kable, Fox and Lunn (1928) experimented with a 13-hr. light day from the first of October to the last of March with pullets and hens. The pullets gave an increased production but the yearling hens that had been lighted as pullets produced fewer eggs than yearling hens without lights. They conclude that for pullets lighting is profitable.

Barker (1929) gives the data shown in Table 54 for laying flocks that were provided with artificial lights as compared with those that were not provided with artificial lights. In the case of these California flocks, artificial lighting was apparently of no advantage.

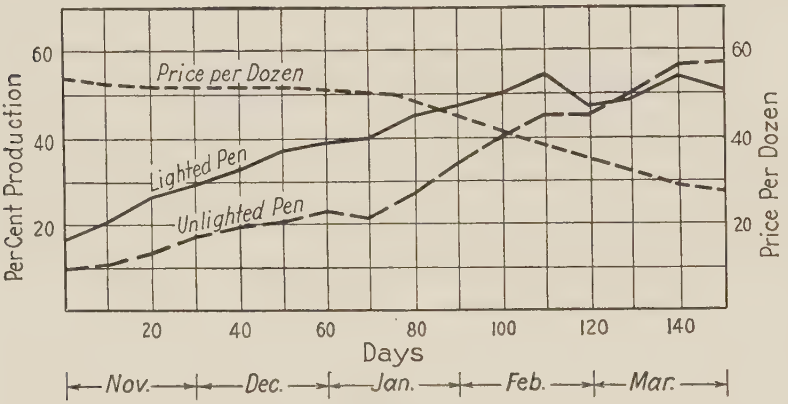


FIG. 158.—Per cent egg production for lighted and unlighted pens, 1923–1924, 1924–1925, 1926–1927. Also, average price of eggs per dozen, 1920–1925. (*After Tomhave and Mumford,* 1927.)

TABLE 54.—COMPARISON OF THE USE OF LIGHTS AND NO LIGHTS IN SANTA CRUZ COUNTY, CALIFORNIA

(Barker, 1929)

	Lights	No lights
Number of flocks	11	14
Average number of hens	10,505	7,676
Average number of eggs per hen	150.2	150.2
Fall eggs per hen	48.1	43.0
Per cent mortality	17.1	15.5
Cost per dozen eggs	33.7	34.2
Farm income per hen	1.82	1.94

Lighting for Hens.—Jones (1929) recommends the use of artificial lights for hens during the summer and fall months. He advises the use of a combination brooding and laying house for keeping the hens from the time the new crop of pullets should be put in the regular laying house until the hens have completed their summer and fall egg production. This combination brooding and laying house is described as a barracks house. The hens are transferred to the barracks house where they are given artificial lights to maintain high egg production, as explained by Jones in the following terms:

On or about Aug. 15 the hens should be segregated and those to be kept for breeders should be put in permanent breeding houses, preferably with range. All outstanding culls should be disposed of and the remaining birds held for egg production should be removed to the barracks house. This leaves all of the remaining laying houses available for early-hatched pullets. If careful management and culling has been practiced, all of the hens in the barracks house should be in fair laying condition; or, if molting, going through what may be classified as a rapid molt or the molt of a high producer.

In order to avoid a drop in production due to molting, artificial light should be turned on at that time. Lighting from 3:00 a. m., standard time, until daylight will do much to increase the food consumption and step up the production of birds in the barracks house. The "night-lunch" system of lighting will prove satisfactory where birds were given the night-lunch system during the previous fall and winter. "Morning light" is, however, considered preferable, as it is easy to get the birds up in the morning but sometimes difficult to hold them up later at night. This system of lighting may continue until winter or until the barracks hens have been sold.

Birds in the barracks house may be fed an additional supply of meat-scrap and an additional amount of milk as an extra stimulant to offset moving and step up food consumption. Additional green food, a better quality of green food, more frequent feeding, or any of the little things in poultry management which tend to increase food consumption, will increase egg production.

Use Lights Properly.—In order to secure the most satisfactory results from the use of lights certain precautions, enumerated by Cray (1925), should always be kept in mind. They are as follows:

1. Make certain that pullets are graded and penned according to age, condition and laying qualities. Each flock should be handled in a different way.
2. Do not use lights before Oct. 1 to 15, as excessive fall production may make it hard to keep the flock in heavy production during the severe winter months. Often the few eggs gained in the fall by starting the lights early are more than lost by the resulting winter slumps.
3. Never give more than 14 hr. of light. Excessive use of lights stimulates overproduction and results in a severe slump later, perhaps throwing the flock into a severe molt.
4. When lights are discontinued in the spring, it must be done very gradually. It is only safe to make a maximum change of 10 min. daily. Discontinuing lights suddenly is certain to produce an unnatural spring molt.
5. Never allow the production to go higher than 55 to 60 per cent under lights, as the flock is almost certain to become thin and molt.
6. Do not use lights on hens that are to be used for breeders until Jan. 1 to 15, and then only to help them back into production.
7. Be regular with lights. Lights must be used every day and at the same time each day for best results.
8. Be sure to feed grain liberally. Thinness is sure to result in at least a partial molt.
9. Be sure that water and feed are available when lights are turned on.
10. Do not turn lights off too early in the spring.
11. Do not stop feeding early and late in the day when lights are finally eliminated.

It is interesting to note that there are cases where artificial lights have been kept burning in laying houses all night long during the winter. This has been practiced for some time in some of the oil-field sections of Texas and Oklahoma, where gas is readily available. Kennard (1929) reports that in some sections of Ohio where natural gas is available the same practice is being followed, apparently with success.

FEEDING THE BREEDERS

The rations used and the methods of feeding the breeders are for the most part the same as those used in feeding the layers except that breeders require less protein than is contained in some of the laying rations and an abundance of sunlight or vitamin D, green feed and a proper balance of calcium and phosphorus are extremely important.

FIG. 159.—Breeding cockerels on range on a Washington State poultry plant. (*Photograph by Hollywood Poultry Farm.*)

The breeders must be fed so that they will produce the highest possible quality of hatching eggs. The importance of vitamins A and D in respect to their influence on hatchability has been discussed on pages 352–358. The relationship between vitamin E and fertility has been discussed on page 362. The value of accessibility to sunlight and the irradiation of the breeders in order that they produce eggs of good hatchability has been discussed on pages 357 and 358. The value of feeding green feeds to improve the hatchability of the eggs has been discussed on page 371. Milk in some form appears to have a very desirable effect in producing eggs of good hatching quality. The importance of the right kind and amount of calcium in the diet of breeders has been discussed on page 347. Besides these important things it has also been pointed out that range on grass sod or other green crop is extremely important.

Carver and Cassel (1925) suggest the following ration for breeders:

The Washington State Breeding Ration

(Carver and Cassel, 1925)

	Parts by Weight
Scratch Ration:	
Wheat	100
Cracked yellow corn	100
Mash Ration:	
Wheat bran	100
Wheat middlings	100
Yellow corn meal	100
Ground oats	100
Meat scraps	40
Fine salt	4

The authors advise feeding grit, oyster shell and charcoal in self-feeding hoppers. The ration given above is fed in the proportion of 60 per cent of scratch to 40 per cent of mash. No lights are used and the breeders are permitted to run outdoors. Green feed and sour milk or buttermilk, at the rate of 6 qt. per 100 breeders, are given daily. If sour milk or buttermilk is not available, condensed buttermilk, 1 qt. per 100 breeders, may be fed. The scratch ration should be fed at the rate of 9 lb. or 6 qt. per 100 breeders daily and it should be scattered in deep litter.

FEEDING BROILERS, ROASTERS AND CAPONS

The demand for chicken meat as an article of diet has been increasing steadily during recent years and this increase would be augmented by a still further improvement in the quality of the meat. Under existing conditions of food production it is imperative that every effort be made to produce stock of such good quality that there will be a minimum of waste. During recent years, however, so much attention has been given to the question of breeding for egg production, that it is quite possible that the best interests of the fattening industry have been sacrificed to some extent at least. However important may be the matter of developing heavy laying strains, there will always be a high proportion of chickens other than those used for laying and breeding purposes and for which it is necessary to develop the most efficient means in preparing for market. Fattening is a finishing process designed to prepare chickens for human consumption in the most economical way. The main object in fattening is to improve the quality of the lean meat, the accumulation of fatty tissue as such being of secondary importance. Improvement in the quality of market chickens leads to increased consumption, which in turn leads to increased demands for prime fattened stock.

Fattening Broilers.—Broilers are young chickens weighing approximately from ½ to 2½ lb. each. In many cases, especially with Leghorns and similar breeds, it is desirable to dispose of the cockerels as broilers when they are separated from the females. Another important source of broilers is the broiler plant, where a specialty is made of raising broilers the year round. In such cases the pullets and cockerels are fed rations that will induce the most rapid growth, broilers averaging 2 lb. each at 10 weeks being not uncommon.

If the chickens grown on range have been fed properly, the cockerels should be in excellent flesh and should not require any fattening ration. In fact, placing them in fattening crates or batteries might even cause them to lose weight. They might be placed in pens or yards of limited size, however, and fattened to good advantage for a period of about 2 weeks. Broilers that are sold alive to go to the packing or commercial fattening houses should never be fattened on the farm.

Rations.—Broiler fattening rations should contain more carbohydrates and fat and less protein than rations for growing chicks. Work done by the U. S. Department of Agriculture, under the direction of McAleer and Pennington (1922), involved a large number of experiments on fattening broilers and other classes of chickens. It was observed that a growing bird such as a broiler requires relatively more protein in the fattening ration than do hens. They obtained good gains in fattening on a ration of 40 per cent of yellow corn meal and 60 per cent of buttermilk, but better gains were obtained when the ration contained a protein concentrate, such as meat scraps, peanut meal and soy-bean meal, these concentrates being used to replace from 5 to 10 per cent of the corn meal. Regarding the kinds of feeds to use, the authors state that "Equally satisfactory results apparently can be obtained by the use of different feedstuffs as well as by the use of different combinations of the same feeds. It is possible to choose from a wide range of feeds which have practically the same fleshing value in a ration. This is fortunate, since it permits the feeder to adapt his ration to market conditions by taking advantage of special prices of certain feeds and also to use feeds available locally." At the same time, the authors observe that coarse oat products should not be used, and it is significant to note that the best gains were usually made when a relatively large proportion of yellow corn meal was used.

Carver and Cassel (1925) recommended the following ration for broilers being fattened in pens:

	Parts by Weight
Yellow corn meal	120
Wheat middlings	20
Wheat bran	20
Ground oat groats	10
Fine meat meal	5
Fine bone meal	5

Many thousands of broilers are raised annually in Delaware, Massachusetts, New Jersey and New Hampshire and generally throughout the northeastern section of the country. For the fattening of broilers in New Jersey, Decker (1926) found that the following ration gave quite satisfactory results:

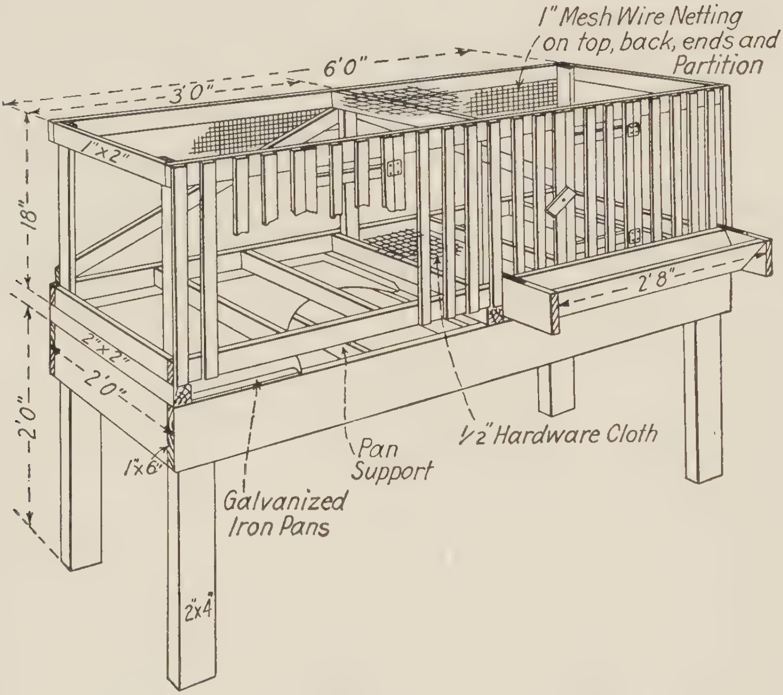
	Parts by Weight
Yellow corn meal	38
Wheat middlings	31
Wheat bran	16
Dried buttermilk	15

Fattening Period.—The proper length of time to fatten broilers depends upon a number of factors, which include the size of the bird, the kind of feed used, the conditions under which fattening is carried on and the degree of finishing required. Under ordinary conditions, however, if the broilers at the beginning of the fattening period are in excellent physical condition, fattening is usually continued for about 10 to 14 days. The broilers are fed two or three times daily, the former being preferable unless the birds are fed early in the morning, at noon and late in the evening. Feed should never be left in the troughs for any length of time; if it is not eaten up within half an hour after being fed, the remainder should be removed from the troughs. In the case of broilers raised in batteries from hatching time, when cod-liver oil is sometimes used to supply vitamin D, the cod-liver oil should be eliminated from the ration two weeks before the broilers are to be killed.

Fattening Roasters and Capons.—The fattening of roasters and capons is based upon the same principles as the fattening of broilers, except that fattening rations for roasters and capons require relatively smaller amounts of protein. Because of their greater maturity, roasters and capons are inclined to add more fat to their tissues than broilers.

When farmers and commercial poultry raisers are able to dispose of their roasters and capons on the local market, fattening is advisable, a suitable fattening crate for farm use being shown below.

On the other hand, many farmers do not have sufficiently good market facilities to dispose of fattened birds to advantage. The great bulk of the cockerels raised on the farms are sold to commercial packing houses and in such cases the cockerels should be sold direct from the range without being fattened.



A two-compartment fattening crate suitable for fattening chickens on the farm. (*Plan by Mo. Agr. Exp. Sta.*)

Rations.—Lee (1911) conducted an extensive investigation of fattening methods employed in a number of packing houses and made a number of interesting observations concerning the results secured. Two rations were used in most of the experiments; (1) containing 60 per cent of corn meal and 40 per cent of low-grade flour; (2) consisting of 58 per cent of corn meal, 36 per cent of oat flour and 6 per cent of tallow. Both rations were mixed with condensed buttermilk, which was diluted by adding 2 parts of water to 1 part of condensed buttermilk. The results secured are shown in Table 55.

Lee observed that ration number one gave more uniform results than ration number two, although it took the same average amount of grain to produce a pound of gain in the case of each ration. In both cases the cheapest gains were made when the chickens were fed for 7 days. With the first ration the lowest average cost of gain was made by the chickens fed for 7 and 8 days, whereas, with the second ration the lowest average cost of gain was made by the chickens fed for 14 and 15 days. With both rations the average number of pounds of grain to produce 1 lb. of gain in

Table 55.—Summary of Results in Fattening Roasters in Packing Houses, Arranged According to Length of Feeding Period
(Lee, 1911)

Ration	Days fed	Number of birds	Average weight, pounds	Average gain, per cent	Average pounds grain per pound gain
1	10	2,068	2.51	18.5	4.04
1	9	10,360	2.40	19.4	3.52
1	8	11,878	2.55	17.2	3.37
1	7	15,731	2.39	19.2	2.68
1	6	3,907	2.18	13.1	3.66
Total and average		43,944	2.42	18.1	3.26
2	15	892	1.90	38.7	2.58
2	14	6,720	2.18	36.8	2.80
2	13	8,464	2.54	23.2	3.16
2	12	1,657	3.22	12.4	4.26
2	11	644	3.98	8.7	5.07
2	10	7,836	3.24	13.6	3.71
2	9	7,368	3.18	14.7	3.66
2	8	12,199	2.81	17.0	3.16
2	7	14,841	2.69	16.4	2.96
2	6	1,085	3.08	11.6	2.96
Total and average		61,706	2.82	18.7	3.26

flesh was 3.26. The general-purpose breeds made more economical gains than the lighter breeds.

Jull (1916) observed that less grain was required to produce one pound of gain in flesh when roasters were fed corn meal only than when on a ration of equal parts corn meal, oatmeal feed and ground buckwheat or on a ration of oatmeal feed only. Less grain was required to produce one pound of gain in fattening for two weeks as compared with three weeks.

Dougherty (1922) recommended the following fattening ration for California, where barley is more readily available than corn:

	Parts by Weight
Barley meal	2
Corn meal	1
Shorts	1
Liquid buttermilk	8 to 10

W. R. Graham (1922) reports that he secured the best results in fattening roasters by using the following ration:

	Parts by Weight
Finely ground oats	2
Finely ground buckwheat	2
Finely ground corn	1
Sour skim milk	10 to 12

Jull and Maw (1923*b*, 1923*c*) fed different combinations of corn meal, oatmeal and buckwheat, moistened with water and with sour skim milk and in some cases supplemented with meat scraps. There was little apparent difference regarding the proportions of the three grains used, but the use of sour skim milk instead of water to moisten the mash reduced the average number of pounds of grain to produce one pound of gain in flesh from approximately 7 to approximately 3½. They found that the size of the chicken determined the proper length of time for fattening, chickens averaging 4 lb. in weight fattening best in 10 days and chickens averaging 3 lb. in weight fattening best in 14 days.

The Iowa Agricultural Experiment Station (1925) used rations consisting of equal parts of corn meal and oat flour and found that feeding twice daily gave the best gains and greatest economy during the 14-day fattening period, while feeding three times daily produced the best and most economical gains during the 7- and 11-day fattening periods.

Dowden (1927) discusses the methods of fattening employed in the famous Sussex fattening district of England and says that only Sussex ground oats are used, oats from the stone-grinding process being preferred. The ground oats are mixed with half skim milk and half water or, if skim milk is not available, dried skim milk is used.

Method of Feeding.—The results in fattening roasters depend not only upon the kind of grains used but also upon the method of feeding. In some respects the latter is more important than the former. It is especially important, for instance, to feed lightly the first few days because overfeeding during this time may easily spoil the birds' appetites and put them out of condition.

The following general observations by Jull and Lee (1927) apply in all cases of fattening:

> Feed very lightly twice a day for about the first two days, then for the rest of the period feed them all they will eat twice a day, but do not leave feed before them. The length of time required to fatten poultry properly depends very largely on the age and fleshing condition of the birds when they are put into the fattening pen, crate, or battery. Young birds require a longer period for fattening than old birds. Experience has shown that cockerels weighing about 4 lb. each increase 1 lb. in flesh after about 10 days of careful feeding. At commercial fattening plants the fattening period does not last over two weeks. Experienced private fatteners sometimes feed for as long as three weeks, but under such circumstances feeding must be done very carefully, especially during the last week. The proper length of time to feed any particular lot of chickens can be determined best by observing the condition of fleshing from day to day.

Capons should be fattened in the same manner as roasters, except that they are usually fattened in pens. The capon, kept long enough, will develop into a larger bird than a cockerel and the best market prices are usually obtained in January and February, so that capons must be kept in a good growing condition for a longer period than cockerels. During the growing season capons should be fed the same as cockerels raised for roasters, and the same fattening rations that are used for roasters should be used for capons.

CHAPTER XXVI

DISEASES AND PARASITES AND THEIR CONTROL

Parasites and diseases of various kinds cause an enormous loss in the chicken industry every year. It is estimated, for instance, that the annual loss from mortality in growing chicks is at least $18,000,000 and the annual loss in mortality among laying hens is at least $20,000,000. To these losses must be added the mortality of chickens in poultry-packing plants, retarded growth and decreased egg production among birds that live but are infested with parasites and infected with disease organisms.

Dr. J. R. Mohler (1927, 1928) gives an excellent resume of the development of the poultry industry and offers a number of definite suggestions regarding the control of disease. Since a number of the diseases affecting chickens are communicable diseases, Dr. Mohler's remarks are of particular significance from the standpoint of safeguarding the industry from further ravages of diseases. His observations are as follows:

> Although coexistent with the earliest career of the colonists of North America, the poultry industry up to comparatively recent times has constituted a rather incidental enterprise of the American farmer, usually managed by the housewife or children of the family. As a rule, the occurrence of disease under these conditions was either entirely unsuspected, as the fowls were allowed the run of the farm and shifted largely for themselves, or else regarded as of so little consequence as to merit no particular concern. An occasional dead hen was thrown unceremoniously into the hog pen or perhaps left to lie where the unfortunate creature had expired, attended only by such obsequies as might be offered on the part of buzzards, rats or other disease-disseminating scavengers. The last decade, however, has witnessed an amazing change in the scope and methods of poultry and egg production, as the industry has rapidly forged to the front line of dignified commercially productive enterprises. This development of the industry has been aptly termed one of the romances of our age. No longer is the humble hen an incidental, uninteresting and obscure member of the farm family, left to the chance fare that might fall to the ground from the corn crib or manger, but she is in many instances a recognized asset, a chief source of income, and as such is pampered and favored with the best of feed, shelter and attention. The legal recognition of the poultry industry has scarcely kept pace with its unprecedented growth in commercial importance. Laws of the land relating to live stock have frequently been so interpreted as relating only to domestic animals of the mammalian class but not to the feathered bipeds.
>
> This lack of a legal status as regards the poultry industry has been one of its most serious handicaps. It is partially because of such a lack that, thus far,

little definite information is at hand in relation to the geographical distribution of various poultry diseases, nor are any statistical data available as to the ratio of mortality of any particular disease. In individual cases, such as that of avian tuberculosis, the Bureau (Bureau of Animal Industry, U. S. Department of Agriculture) has been able to engage in a rather extensive survey, with much valuable information forthcoming as a result. However, under the laws governing our activities the Bureau has thus far been restricted in its sanitary policing as regards the nation-wide poultry disease problems. Comprehensive and far-reaching control measures have been impossible of legal enactment or enforcement, and the keen solicitude of the nation's veterinary staff has been technically unable to find expression. In spite of these weighty handicaps, the young and vigorous industry has continued to press toward the fore, until at present our chickens are increasing relatively faster than our population.

I feel strongly that the most effective control of poultry diseases in the United States must be based largely on the efforts of poultry owners themselves, which naturally would include the employment of the veterinarian skilled in poultry diseases. Such control is first an individual problem. And only when individuals can not or do not handle a dangerous situation is there need for governmental or state action. The objects of such action should be threefold: to protect domestic poultry from foreign contagion, to prevent the spread of poultry diseases from state to state, and to eradicate communicable diseases within a state when they appear.

These are essential functions for the protection of any state or country engaged in the production of poultry and poultry products, in order to conserve this valuable source of food and revenue. There can be no doubt of the mutual advantage that would come from closer cooperation in these matters.

Among the fundamentals which deserve special consideration are the following:

Each poultry-raising state should establish a competent veterinary poultry service, which should include poultry research laboratories and competent workers.

Laws and regulations should be framed with the object of preventing the spread of communicable diseases within a state, the transmission of infection from one state to another, and the introduction of infection from abroad. They should be based on dependable scientific information and not on business expediency nor for the purpose of furthering commercial ends.

Thorough surveys should be made by the veterinary organizations of each state, at regular intervals, to ascertain what contagious diseases and harmful parasites are present in the state.

There should be an exchange of official information between states, at regular intervals, covering the results obtained through surveys and research work.

Funds should be constantly available to control or eradicate outbreaks of communicable diseases, especially the destructive foreign pests.

THE IMPORTANCE OF SANITATION

Everyone should appreciate the fact that when chickens are kept under strictly sanitary conditions there should be relatively little trouble from parasites and disease. It is an established fact, however, that very few flocks of chicks are kept under strictly sanitary conditions. It is a further fact that but few poultry raisers have an adequate conception of what sanitation really means. There are certain diseases, of course, such as pullorum disease, that cannot be controlled by sanitation alone. The importance of sanitation in keeping chickens in a good state of health at all times is discussed by Van Es and Martin (1923), whose observations are as follows:

> Sanitation consists in the establishment and maintenance of surroundings fit and safe for animals to live in. In connection with sanitation the term "surroundings" must be made to include everything with which an animal comes in contact, so that under this heading consideration must be given to feed, water, and air as well as to the housing, yards, and soil.
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> The hygienic aspect of the soil is of particular interest because on it are deposited the body wastes, which may contain the bacteria of disease or the eggs of internal parasites. Large numbers of fowls inhabiting small areas of soil may so contaminate the latter that certain diseases become more or less permanently established. This actually happens on several farmyards and often renders the eradication of disease extremely difficult. When soil is left unpopulated for a time, it rids itself of the harmful materials mentioned; but when there is a continued concentration of a large number of animals on a comparatively small area of soil, the latter gradually assumes the quality of sewage or body wastes. No species of animal can persist in a more or less intimate contact with its own body wastes without incurring extraordinary hazards of becoming involved in outbreaks of disease.
>
> Even in the maintenance and exploitation of the farmyard flock, those facts must be reckoned with. While at the present time rotation of poultry yards is not as urgently needed in Nebraska as that of hog yards, sooner or later the disease and parasite problem will compel this. Even now a rotation of the yards has its place. The poultry house should communicate with two yards properly fenced, one used by the poultry and the other under cultivation. The areas should be large enough and be provided with shade. The poultry should be enclosed there during spring and summer, while during fall and winter they may be given the freedom of the farmstead and in the spring be transferred to the second yard for the following season.
>
> Poultry yards, as well as the building sites for poultry houses, should be selected with a view to dryness and shelter. A sandy, gravelly soil is always to be preferred for the purpose mentioned, while the topography should be such as to provide a free, natural drainage. Whenever this is not obtainable, some artificial means of drainage should be established. In poultry yards surface water should not be permitted to accumulate in low places, wagon ruts, and the like. Open drains likewise are objectionable.
>
> Of great sanitary importance is the question of pure drinking water. Many poultry diseases are more or less water borne because of contamination by the fowls' droppings. All sources of water supply which are open to such contamination should be removed or discarded. Water fountains, placed some distance above the ground and of which the contents can be protected against pollution, are to be preferred to the open water trough or basin. The water must be

frequently changed and the containers scalded by means of boiling water. The addition of chemicals and medicines to food and water is always unnecessary and quite often harmful.

That sanitation is one of the most important preventive measures against parasites and disease in the raising of live stock has been amply demonstrated by the results secured in what is known as the "McLean County Swine Sanitation System." This system was first outlined by Ransom (1918), and developed by Raffensperger and Connelly (1927), the important thing emphasized being the sanitation of the hogs and of their quarters. The same is true in respect to chickens; they must be clean (free from external and internal parasites) and they must be kept in sanitary quarters (clean houses and clean yards).

That the swine sanitation system has been worth while to hog raisers is demonstrated by the results secured, as given in the following excerpt, taken from the U. S. Department of Agriculture Official *Record* (1929):

> Hog producers of Indiana who have tried raising their pigs according to the sanitation system of hog production developed by the Bureau of Animal Industry of the United States Department of Agriculture are enthusiastic over the increase in their profits which the system made possible, says Dr. J. E. Gibson, Federal inspector in charge of hog-cholera control work in Indiana. Doctor Gibson reports that the increase in returns resulting from the use of the system, over the returns received by the same producers under their former methods, has been about $6 per pig on an average. The system involves the farrowing and raising of pigs under such conditions that they do not have parasites, especially roundworms, which if not controlled retard growth and cause death in many instances.

Value of Sanitation.—The practical value of providing adequate sanitary conditions in raising chickens has been demonstrated by the results of the various Grow Healthy Chicks Campaigns as given on pages 217 and 220. Growing chicks reared on range should always be grown on clean range, away from the adult flock and away from other classes of live stock. It is only in this way that the chicks can be kept comparatively free from lice, mites, internal parasites and diseases. The proper and regular disinfection of the brooding apparatus and houses will help to keep disease organisms in abeyance.

The usual mortality occurring in the laying stocks of the country could be reduced very materially if flock owners would practice ordinary sanitary precautions. Double or triple yarding arrangements for the laying flock should be provided, as discussed on pages 565 and 567. The suggestion of Van Es and Martin (1923) of providing a double-yarding system where green crops are grown in one yard while the hens are ranging on the other yard should be adopted.

The thorough and regular cleaning of the laying houses is of particular importance in keeping mortality in the laying stock to the minimum. The suggestion is offered here that when the average poultryman cleans his poultry house as he ordinarily cleans it, he could then scrape the floor of the house and gather up several shovels full of filth, which contains millions of disease organisms. In fact, if the average poultryman cleans his laying house two or three times in succession, he will usually still find some dirt left in cracks and crevices and on the floor. The floor should be washed thoroughly with water under pressure, if possible.

Beach and Freeborn (1927) have the following to say regarding preventive measures against disease: "The most effective means of combating diseases and parasites of all species of animals is to prevent their occurrence. This principle is especially applicable to poultry because fowls are commonly kept in such large flocks that disease may spread very rapidly and cause considerable loss before it is recognized. Furthermore, the value of a single fowl is so small that it is impractical to administer individual treatment to many sick ones."

Van Es (1927) makes the statement that "The sanitary program proposed will prevent 75 per cent of poultry diseases; in fact, all the soil-borne diseases." It is obvious, therefore, that the prevention of poultry disease is largely in the hands of the poultryman himself. The more attention given to preventive measures the less occasion there will be for "doctoring" or curing sick chickens. The greater the attention paid to proper sanitation in the houses and on the range the less the worry over losses from communicable diseases and epidemics.

How to Clean and Disinfect.—Lentz (1922-1923) gives the following brief description of the proper manner of cleaning and disinfecting poultry houses and yards:

> Late in June the plant was vacated and preliminary cleaning was started by removing litter, nesting material and overhead straw packing, directly from houses to vehicle, so as to prevent ground contamination. The houses were stripped of all fixtures, the ceilings, walls, and floors were swept, dry scraped, and again swept. The majority of the refuse was scattered over more distant parts of the farm and plowed under. Material which was not suitable for fertilizer purposes was burned. The fences around yards were removed, the grass and weeds were cut and pulled, the yards were carefully "policed" and the debris was burned. The houses were scrubbed, scraped, washed, and rinsed with water under pressure. The dropping boards and larger feed hoppers were cleansed in the same manner outside of the houses and exposed to the sun. The other fixtures, such as trap nests, smaller food and water containers were soaked and scrubbed in a large tank and then exposed to the sun.
>
> Following the preliminary cleansing, all stationary houses and equipment were given a liberal application of a coal-tar disinfectant (3 per cent solution), the germicidal value of which had been previously found to be satisfactory. Gasoline power, fruit spraying apparatus was used. The colony houses and their

equipment received a similar treatment, and were removed to an adjoining plot of ground where they received a second disinfectant before they were occupied.

The yards were plowed, harrowed, limed, leveled and seeded. The ground in the immediate vicinity of the houses was saturated with disinfectant solution. Soil and leaves carried into the houses by winds made sweeping prior to a second disinfection necessary. All smaller articles of equipment, including single trap nests, were immersed in a large tank of disinfectant solution, and received a second disinfection when they were installed.

The large warehouse, the brooder building and the administration building were thoroughly "policed," dry cleaned and disinfectant solution was applied wherever permissible and practicable. Immediately following the second application of disinfectant solution to these buildings, before they were dry, they were subjected to dense and prolonged sulphurous anhydride fumes.

DISEASES AND THEIR CONTROL

There are a large number of diseases that affect chickens, some of them being transmissible. The transmissible diseases, also often referred to as infectious or contagious diseases, are the ones which, above all, are of economic importance. Transmissible diseases are frequently a menace to the whole flock whereas sporadic diseases frequently kill a bird now and then and are of little importance as compared with transmissible diseases. The discussion in this book is concerned principally with the prevention and control of the important chicken diseases, the more important ones being discussed first. Those who wish to secure more detailed information concerning the various diseases that affect chickens should consult Pearl, Surface and Curtis (1915), Beach and Freeborn (1927), Gallagher (1927), Kaupp (1927), and others.

The more important diseases affecting chickens include aspergillosis or brooder pneumonia, catarrh or colds, chicken pox, cholera, coccidiosis, diarrhea, European fowl pest, fowl typhoid, infectious bronchitis, paralysis, pullorum disease, roup and tuberculosis.

Aspergillosis or Brooder Pneumonia.—Heavy losses in chicks sometimes result from aspergillosis or brooder pneumonia, a fungus disease of the lungs and air sacs. The causative agent is *Aspergillus fumigatus*, the growth of which is favored by warmth and moisture.

The fungus can pass through eggshells and it is believed that some outbreaks in brooder chicks may be due to infected eggs which have been in contact with moldy material. More frequently the disease is due to chicks or older birds scratching in moldy hay or straw.

In advanced cases of the disease the birds become listless, breathing becomes difficult, fever develops, the wings droop and there is diarrhea. In young chicks death usually occurs within a few days although older birds may live for a few weeks after the appearance of symptoms.

On post-mortem appearance, the walls of the windpipe, the air passages in the lungs and the air sacs in the abdominal cavity show whitish or yellowish nodules.

In order to prevent an outbreak of the disease, sanitation is necessary; provide clean litter and keep the houses and yards clean at all times. If the disease appears, clean and thoroughly disinfect the house and premises.

Catarrh or Colds.—Catarrh is a mild inflammation of the nasal passages and is usually caused by exposure to drafts or sudden changes in temperature. Birds weak in vigor are more apt to contract catarrh than strong birds. The mucous membrane of the nostrils becomes infected with various organisms and an inflammatory condition develops.

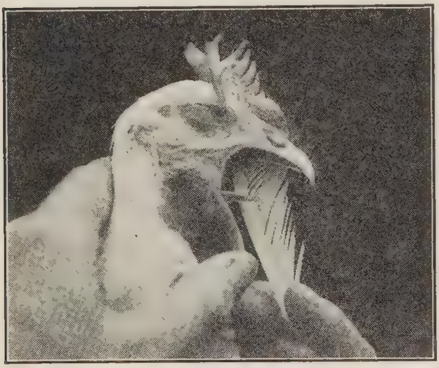

FIG. 160.—Showing method of relieving stoppage of the "tear duct," commonly called "cold" in the eye. (*Photograph by Beach and Freeborn*, 1927.)

Chickens affected with catarrh are usually more or less listless and in severe attacks there is loss of appetite and breathing becomes difficult. A watery discharge from one or both nostrils is frequently evident.

The proper procedure in the way of treatment is to place the affected bird under favorable conditions. This will often cure mild cases but in more severe cases the nostrils should be washed out twice daily with a 3 per cent solution of boric acid or permanganate of potash, using a solution of one teaspoonful to a pint of water.

Catarrh or colds can be avoided if the chickens are kept under proper conditions, which means that the houses should never be overcrowded and they should be free from drafts, although good ventilation should be provided at all times.

Chicken Pox.—Pox nodules on the heads of chickens and yellowish cheesy patches in the mouth and eyes are caused by a virus.

Chicken pox is infectious, which means that it spreads readily from one bird to another. The usual symptoms include pox nodules on the comb, face, earlobes, and wattles and in severe cases, cheesy patches in the mouth and throat. Frequently the eyes become closed and there is difficulty in breathing. Birds affected become dull, weak and lose flesh. The duration of the disease may vary from 3 to 15 days up to several weeks, depending upon the natural resistance of the birds and the conditions under which they are kept, dampness and drafts favoring the spread of the disease.

Affected birds should be removed from the flock and placed in a comfortable room unless the disease is in an advanced stage, in which case the birds should be killed and burned. Whenever the disease makes its appearance in the flock, the houses, drinking vessels and feed hoppers should be disinfected thoroughly. Since drinking water is a fertile source of the spread of chicken pox, every precaution should be taken to make the drinking water antiseptic, which is done by dissolving one-third of a teaspoonful of permanganate of potash in one gallon of water.

If treatment of affected birds is decided upon, the following suggestions should be followed: Rub the chicken pox nodules with a solution of 2 drams of common salt in a quart of warm water, remove the nodules and apply tincture of iodine or a 5 per cent solution of carbolic acid to the diseased surface. Wash the eyes and inject the nostrils with a solution of 2 drams of permanganate of potash in a pint of water or a solution made up of 1½ oz. of boric acid and 1 oz. of powdered borax (borate of soda) dissolved in 1 qt. of water and applied warm.

Vaccination Successful.—Since chicken pox sometimes results in high mortality but more frequently causes a great decrease in egg production, usually in the fall or winter months of the year when egg prices are relatively high, it is most important for poultry raisers to recognize that there is a very practical and efficient way of avoiding an outbreak of the disease in the laying flock. The pullets may be vaccinated a month or so before they are put in the laying houses. The fundamental principle of vaccination against chicken pox is discussed by Kalkus (1929) in the following terms:

> Immunization is the process of rendering man or animal proof against some specific disease. Effective methods of immunization as a means of prevention are now successfully used in the case of many infectious diseases. Nearly everyone is aware of the fact that one attack followed by recovery in the case of many infectious diseases is a means of insuring protection against further attacks of the same affliction.
>
> Scientific investigation has revealed the fact that immunity may be induced artificially by the injection of virus, vaccine, serum, and other biological products. Furthermore, in the case of some diseases this is the only effective and practical way of preventing them.
>
> For a number of years the need for developing a successful method of vaccination for effectively immunizing birds against fowl pox has been recognized. Our present knowledge of this disease indicates that proper flock management, sanitation, disinfection and individual treatment may be of some value in controlling it but this method is far from being completely satisfactory. The virus or causative agent of the disease is extremely resistant to external influences; it may live for years in a dried condition; it is easily carried from place to place in the form of scabs and it is difficult to kill by ordinary methods of disinfection.

The vaccination of chickens against chicken pox is discussed by Marx and Sticker (1913), Beach (1920*a*, 1920*b*), van Heelsbergen (1925), Johnson (1927), Doyle (1929) and Sawyer (1929). Kalkus (1929) says that "in order to secure the best results vaccination with virus should be done by one who not only has had experience in its use but who understands thoroughly the fundamental principles in its production and its effect upon the bird's body."

The prevention of chicken pox by vaccination is discussed by Johnson (1927) in the following terms:

> Virus vaccination may be successfully used in commercial flocks to prevent fowl pox. This method produces immunity against experimental as well as natural inoculation. Immunity to comb infection follows leg vaccination. Immunity to leg infection follows comb inoculation.

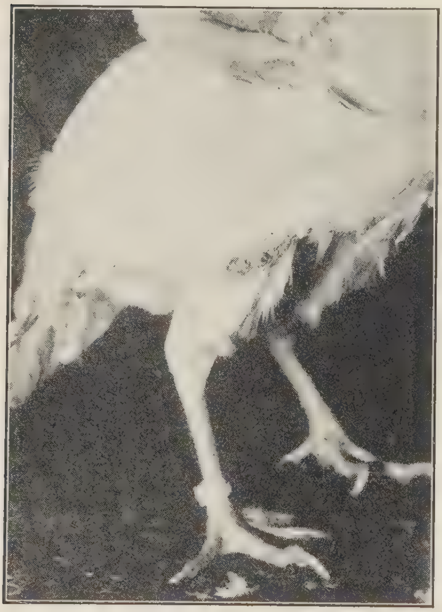

FIG. 161.—Vaccination on leg, 18 days after vaccine had been applied by piercing the skin in two places with a very sharp pointed dissecting needle, which had been dipped in vaccine. (*Photograph by Western Wash. Exp. Sta.*)

> Inoculation of 13 fowls 23 days after vaccination did not produce pox. Fowls immunized by virus-vaccination when 4 months of age were immune to experimental inoculation slightly less than 11 months later. The scarified comb of susceptible fowls consistently develops pox. The uninjured comb of susceptible fowls is insusceptible to pox.
>
> Vigorous fowls about four months of age are particularly suitable for vaccination. Laying fowls, fowls under two months of age, and weak young fowls are particularly likely to develop unfavorable reactions and high mortality. Observations indicate that young stock is less likely to develop natural infection then mature stock.
>
> The indications are that coninuous application of virus-vaccination may produce strains with slightly increased resistance to pox and that lower mortality may later be expected from vaccination.
>
> One vaccinator, with assistance for catching and holding the fowls, can vaccinate about 400 fowls per hour. The cost of vaccination is less than any previously used.

The observations of Sawyer (1929) are given as follows:

> In the general practice of cutaneous vaccination with fowl pox virus, a definite amount of vaccine should be applied. This is probably not done when vaccine

is applied with a swab. A few experimental birds have been immunized against pox by piercing the skin of the leg in two places with a very short dissecting needle, which had been dipped in the vaccine. This leaves a drop of the vaccine on the area which causes a pox scab to develop in about fourteen days.

Cutaneous (skin) application of a vaccine containing fowl pox virus has produced complete protection against subsequent natural infection of fowl pox in over 5,000 chickens at the Western Washington Experiment Station during the past three years. Over 500 of these vaccinated birds have been inoculated with virus on the comb and four birds have developed lesions of pox.

Immunity to artificial inoculation has lasted two years in 79 out of 80 birds in one of these groups. Virus applied to denuded feather folicles without scarification will produce immunity to subsequent artificial comb inoculation.

Vaccination as conducted here was dangerous when applied to laying birds during cold weather. Vigorous birds between three and four months of age were vaccinated during warm weather with no apparent bad results. Birds which lack vigor should not be vaccinated with virus. Field trials on 37 pullet flocks during the summer of 1928 were not satisfactory in all flocks. A high mortality followed vaccination reaction in a few flocks and natural pox infection was reported in eight flocks during the fall. These cases of natural infection included before Jan. 1, 1929 slightly more than 1 per cent of 55,000 birds which were vaccinated in these field trials.

Poultry raisers should appreciate the fact that the ravages of chicken pox can be largely eliminated by the proper vaccination of the pullet flock one month or so in advance of their being put into the laying house.

Cholera.—The cause, symptoms, post-mortem appearance and treatment of cholera are discussed by Gallagher (1927) in the following terms:

Cholera is a highly infectious, rapidly fatal disease of all domesticated birds. Birds of any age are susceptible. It is caused by *Pasteurella cholerae gallinarum* (or *P. avicida*), a germ which multiplies to enormous numbers in the blood and various organs of the body, producing a septicemia or blood poisoning. The disease is carried by sick or recently recovered birds which have been placed in a healthy flock, by wild birds, or by persons, animals or poultry utensils which have been on infected premises. It spreads rapidly throughout the flock, owing to the fact that the first birds to become infected give off great numbers of the germs in their droppings and these germs are picked up by the other birds in feeding and drinking.

The first symptom is a yellowish coloration of the droppings. This is followed by yellowish, brownish or greenish diarrhea. The bird becomes droopy, feverish, and sleepy and sits with the head drawn down to the body or turned backward and resting in the feathers about the wing. Appetite diminishes and thirst increases. Breathing becomes difficult and may be heard at some distance. Finally the weakness is such that the bird can not stand but lies with the beak resting on the ground. It sleeps so soundly for some time before death that it can hardly be aroused. The comb and wattles may be a dark bluish red, and the skin of the breast and abdomen is frequently reddened.

In very acute cases no symptoms are seen; the birds may be found dead under the roosts or they may fall while feeding or moving about and die in a short time. During an acute outbreak sickness is seldom noticed more than 24 hr. before death, which usually occurs within three days from the time of infection.

Cholera may destroy the greater part of a flock in a week and then disappear, or it may linger in a chronic form for months, only occasionally killing a bird. The chronic form is characterized by a continually increasing weakness, loss of weight, paleness of head and, finally, an exhausting diarrhea. Sometimes one or more joints of the wings or legs swell, the bird becomes lame, and, later, the swellings break and discharge a creamy or cheesy mass.

The heart has red spots or hemorrhages on its surface. The first portion of the intestines is congested and hemorrhagic and the contents consist of a pasty mass, which may be bloodstained. The vessels of the visceral organs are congested. The liver may be enlarged and darker in color and the spleen may be swollen. A sticky fluid is frequently present in the mouth and nostrils.

Since treatment of affected birds is futile, the aim should be to prevent so far as possible the spread of infection. The first fowls showing acute feverish symptoms should be destroyed by a method which would guard against the contamination of the premises by infected blood. The carcasses should be burned or buried deep. The healthy fowls should be moved to new quarters, if possible, and carefully watched for signs of disease. Houses and runs should be thoroughly cleaned at frequent intervals and disinfected with compound solution of cresol in 3 per cent solution, or a reliable coal-tar disinfectant in proper dilution. The drinking water may be made antiseptic by adding one-third teaspoonful of permanganate of potash to each gallon, a procedure which tends to check the spread of disease through the water.

Further observations on cholera may be obtained by consulting Hadley and Amison (1911), Hadley (1912, 1914*c*, 1914*d*), Beach (1922), Van Es (1922) and Kaupp and Dearstyne (1925).

Diarrhea.—In the case of nearly all infectious diseases there is usually some diarrhea present. It is frequently the result of digestive disturbances, which may be caused by a variety of conditions.

The proper treatment is to give affected birds Epsom salts in the proportion of one-half teaspoonsful to each adult bird. For growing chickens reduce the proportion of Epsom salts according to the size of the birds. The best way to give the Epsom salts is to dissolve them in warm water and then give them in a moist mash.

European Fowl Pest.—European fowl pest appeared in the United States for the first time in 1924. It is a very acute, infectious disease which has caused heavy mortality in different parts of Europe since it was first discovered in Italy in 1878. The causative agent of the disease is an ultra-microscopic virus.

The symptoms of chickens affected with European fowl pest include a ruffled condition of the feathers, loss of appetite, droopiness, darkening and swelling of the comb and wattles, and in advanced cases a clogging up of the eyes and nostrils with a sticky exudate. Death usually occurs in from two to five days and, since the disease is so highly infectious, a large part of the flock may die in a relatively short time.

Diseased birds cannot be treated successfully so that the best the poultryman can do is to prevent its appearance in the flock in so far as possible. This can be accomplished best by avoiding the purchase of stock from places where the disease exists. If the disease does break out, diseased birds should be removed from the flock immediately and the healthy birds should be moved to new quarters. The diseased birds should be killed and burned, every precaution being taken to avoid spilling any blood on any part of the premises. The houses and equipment should be thoroughly disinfected with a 3 per cent solution of cresol compound. If the disease occurs in birds being shipped to market, all shipping equipment, including coops, crates and live-poultry cars, should be cleaned and thoroughly disinfected. Beaudette (1925) recommends quarantining the poultry plant where the disease occurs to avoid spreading the disease to other plants.

Fowl Typhoid.—Fowl typhoid is an infectious disease occurring in adult chickens and is caused by an organism called *Salmonella sanguinaria.* The disease has been studied by a large number of workers and anyone desiring to consult the literature is referred to Hadley, Elkins and Caldwell (1918), May and Tibbetts (1923), Kaupp and Dearstyne (1924), Beaudette (1927) and Lambert and Knox (1928*a*).

Fowl typhoid may be introduced into a flock by infected birds or infected material, such as shoes and litter. The symptoms in infected chickens include dullness, loss of appetite and fever. The droppings are soft and greenish or yellowish in color. The symptoms may be observed in from four to six days after the birds become infected. Because the disease is highly infectious all diseased birds should be removed from the flock immediately and killed and burned. The healthy birds should be moved to new quarters, if possible, and the houses and equipment should be thoroughly cleaned and disinfected with a 3 per cent cresol compound.

Lambert and Knox (1928*b*) have demonstrated that resistance to fowl typhoid is inherited, multiple factors being involved. It should be possible, therefore, to breed a strain of chickens naturally resistant to fowl typhoid.

Infectious Bronchitis.—Infectious bronchitis is a very infectious disease that has increased in seriousness during recent years. It is sometimes called "flu" and "influenza" and is more serious in pullets and cockerels than in older birds.

It is caused by a filterable virus. The symptoms include ruffled feathers, loss of appetite and difficulty in breathing. Death usually follows in three or four days, being caused by breathing becoming impossible due to exudates which obstruct the windpipe.

It is apparently impossible to treat diseased birds successfully. Overcrowding and poor ventilation are apparently responsible for the rapid spreading of the disease when it breaks out. Rigid sanitation is the best preventive measure. The same suggestions as given under European fowl pest should be followed in case infectious bronchitis breaks out.

Paralysis.—A comparatively new disease, commonly known as "range paralysis," has become quite serious in some sections of the country. The causative agent apparently has not been determined. Pappenheimer, Dunn and Cone (1929*a*) state that "symptoms appear between the third and eighteenth months. Typical clinical cases have not been observed outside of these limits. The conspicuous symptoms are (*a*) asymmetrical, partial and progressive paralysis of the wings and both legs, and rarely of neck muscles; (*b*) occasional grey discoloration of iris, with blindness. Nutrition is usually preserved."

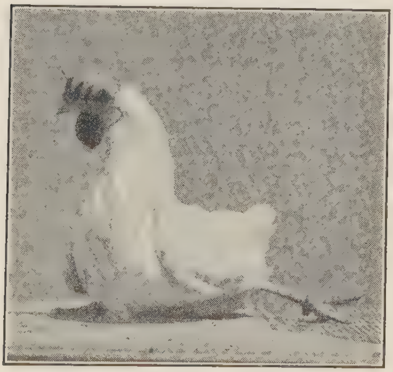

FIG. 162.—A stage of fowl paralysis. (*Photograph by Pappenheimer, Dunn and Cone*, 1929.)

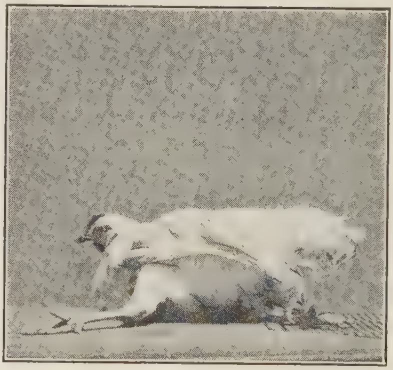

FIG. 163.—Fowl paralysis terminal stage, complete prostration. (*Photograph by Pappenheimer, Dunn and Cone*, 1929.)

The same authors (1929*b*) have demonstrated that the disease can be transmitted. May, Tittsler and Goodner (1925) state that "control seems possible through proper rotation methods and sanitation." Stafseth and Johnson (1927) discuss measures of treatment and prevention in the following terms:

> It is questionable whether any treatment, known at this time, can be considered a specific cure for this disease. However, within recent times two new treatments have been suggested both of which seem deserving of further trial. One consists in putting one teaspoonful of quinine sulphate into each gallon of drinking water, keeping this solution before the birds while the disease exists in the flock. As quinine sulphate is expensive and only slightly soluble in water one should add fresh water as needed until all of the drug is entirely dissolved before adding a new dose. The water must, of course, be protected so that it

cannot be contaminated with droppings. Isolation and treating of affected birds only, may prove effective and, surely, more economical than treating the entire flock provided the apparently healthy birds are placed in clean quarters or on entirely fresh ground.

Iodine vermicide in one ounce doses for adult birds should also be given a trial as there are reasons to believe that it may be of value in treating coccidiosis. This drug is given by means of a one ounce infant enema syringe attached to a female catheter No. 5, the catheter being passed down the esophagus directly into the gizzard.

Pullorum Disease.—The pullorum disease, which frequently causes such enormous losses among chicks, has been called "bacillary white diarrhea." The disease is caused by an organism called *Salmonella pullorum,* which infects the ovary of the hen.

Because of the heavy mortality frequently resulting from the pullorum disease, a vast amount of investigational work has been done during recent years. A very comprehensive survey of work done has been given by Hooker (1925) so that but few other references are necessary.

The nature of the disease and preventive measures are discussed by Gallagher (1927) as follows:

> Chicks which recover from bacillary white diarrhea frequently retain the causative organism, *S. pullorum,* in their bodies, where it later localizes in the active ovary. The disease may be contracted also by feeding with fowls that harbor the organism or by eating infected eggs. In some cases from 50 to 70 per cent of a flock of hens may be affected. Many of the eggs laid by these hens carry the microorganism, and chicks hatched from them spread the disease to others of the brood. Chicks are highly susceptible to infection during the first 48 hr. of life, but are practically insusceptible after the fifth day. Nearly all the exposed chicks become infected and the death rate may reach 100 per cent.
>
> Another source of infection is through incubators and brooders which have previously held diseased chicks. Day-old chicks from infected flocks may carry infection to other points and contaminate brooders or infect other flocks.
>
> In acute outbreaks or in experimental infection the hen becomes droopy, the feathers ruffed, the comb and wattles pale, and the head drawn back. There is loss of appetite, and diarrhea is often in evidence. Death follows in from one to several days. In the ordinary form of the disease, however, no external symptoms are observed, and it is only through the presence of white diarrhea in the chicks or the detection of diseased ovaries in slaughtered hens that attention is directed to the presence of the disease in a flock.
>
> In baby chicks infected in the egg symptoms appear immediately after hatching or in a day or so. Chicks which contract the disease after hatching show symptoms in from 4 to 10 days later. Deaths occur from the time of hatching until about 3 weeks later, when the brood is practically wiped out.
>
> The ovary presents a characteristic appearance. The partially or wholly developed yolks are angular in outline, shrunken, hard, and discolored to a dark-brown or greenish color. At times yolks containing dark fluid are present.

The presence of the disease in a flock may be detected by post-mortem examination, by laboratory methods, or by other special tests.

The nature of the affection renders treatment futile. Flocks which harbor the infection should not be used for breeding purposes. The cycle of infection established by the hen, the egg, the recovered baby chick, and the pullet indicates that it is not advisable to save for breeders any chicks which have been exposed to an outbreak of bacillary white diarrhea. Where the value of the breed makes its perpetuation desirable, careful incubation may result in the raising of a clean brood of chicks from an infected flock. The trays of the incubator are divided, one or two days before hatching time, into compartments large enough for from 5 to 10 chicks, as the owner may decide. These trays are so constructed as to

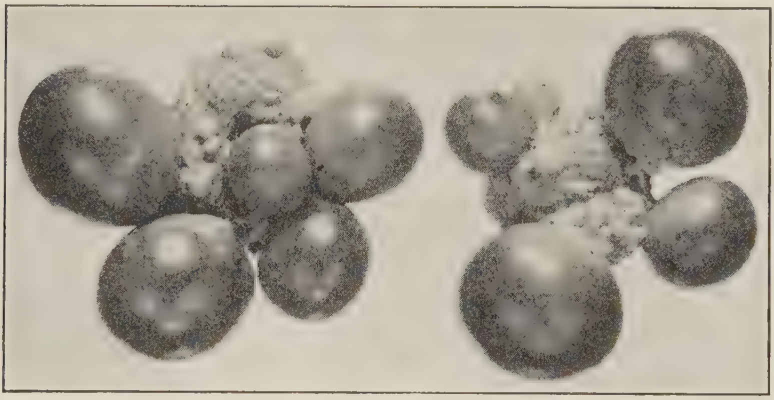

Fig. 164.—Ovaries from two hens that are free from the pullorum disease (bacillary white diarrhea). Note the round, regular shape of the ova. (*From Edwards and Hull*, 1928.)

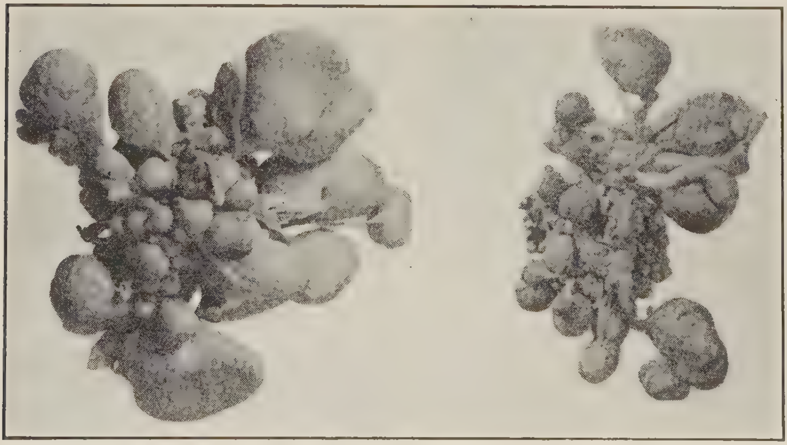

Fig. 165.—Ovaries from two hens that are carriers of the pullorum disease (bacillary white diarrhea). Practically all of the ova are abnormal. (*From Edwards and Hull*, 1928.)

prevent the exposure of chicks in one compartment to those in another. The trays should be darkened with burlap curtains, thus decreasing the tendency of the young chicks to pick at one another's droppings and thus possibly infect themselves with the diarrhea germs. The birds should be kept isolated in this manner for at least three days or transferred to a brooder provided with similar arrangements for segregation. Should disease break out, the chicks in the particular compartment are to be removed and disposed of. The attendant should carefully disinfect the compartment and his hands before caring for the others. After a few days the danger from infection is very slight and all the brood may be allowed to run together.

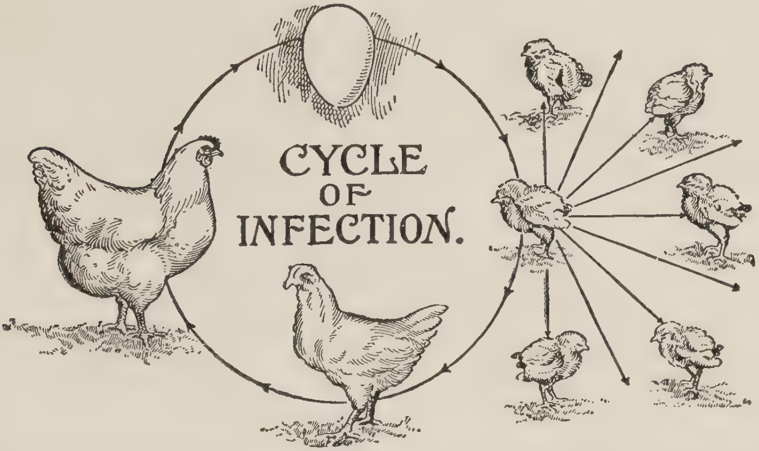

FIG. 166.—The pullorum disease (bacillary white diarrhea) is transmitted from the hen to the chick through the egg. The only known reliable method of controlling the disease is by testing each bird with the agglutination test and removing all reactors from the breeding pen. (*From Rettger, Kirkpatrick and Jones.*)

Incubators Transmit the Disease.—Hinshaw, Upp and Moore (1926) have demonstrated that the disease is transmitted in incubators. The U. S. Department of Agriculture, after an exhaustive study of the transmission of the disease in various types of incubators, concluded that it is transmitted in all of the common types of incubators. It is obvious, therefore, that it is most desirable to remove carriers of the disease among the breeders. Moreover, Asmundson and Biely (1928) have shown that infected hens lay less than non-infected hens.

Agglutination Testing to Detect Reactors.—A simple and practical agglutination test for locating carriers of the pullorum disease is described by Bunyea, Hall and Dorset (1929) and, because of its importance in reducing mortality in young chicks, poultrymen are urged to have their local veterinarian or the state poultry pathologist use the method.

Roberts and Card (1926) make the following interesting observations regarding the inheritance of resistance to pullorum disease:

Great variation exists among chickens with respect to their resistance to infection with *S. pullora.* The occurrence of resistant chicks is such as to indicate a natural resistance that is hereditary. Chicks from certain hens are much more resistant to infection than are the chicks from other hens, when the measure of resistance is the percentage of chicks that survive an inoculation, at approximately 24 hr. of age, with a pure culture of *S. pullora.* The occurrence of resistance is sufficiently consistent among chicks from certain hens and flocks to suggest that it may be possible to establish a strain of fowls that will be highly resistant to infection with *S. pullora.*

Roup.—Roup or contagious catarrh has long been a serious menace to the chicken industry. It is a disease which attacks principally the membranes lining the eyes, the nostrils and the windpipe and is inclined to be more prevalent during damp, cold or changeable weather.

The discussion of roup by Van Es and Martin (1923) is brief but complete and is given here.

> The causative factor of this more benign disease which we tentatively call "roup" is not known. It is quite possible that under certain conditions to which the fowls are exposed a number of bacteria normally present on the mucous membranes are induced to assume disease producing functions in the same manner that the common colds of folks come about. It is further possible that the preponderance of a certain bacterial species may cause the disease to present itself with special features.
>
> There is sufficient evidence that whatever the cause or causes of roup may be, their action is stimulated or made possible by such insanitary conditions as overcrowding and poor ventilation, while exposure to cold draughts, low temperatures and damp weather is correctly regarded as promoting the occurrence of the disease.
>
> Under the conditions mentioned, several cases of roup may occur in a flock at a given time; but, on the whole, regular outbreaks such as are seen in canker are not common.
>
> The most conspicuous sign of the disease is the appearance of a sticky, tough discharge from one or both nostrils. This discharge has a tendency to dry around the nostrils as a yellow incrustation. It arises from a superficially inflamed mucous membrane; and as this inflammatory reaction extends into the adjacent sinuses from which the mucus cannot readily drain away, there accumulates in those cavities a rather dry, cheesy mass which causes marble-sized enlargements to protrude below the eyes. The deeper air passages may become involved in this catarrhal condition and as a result a rattling sound produced by the air moving within will be observed.
>
> The disease causes discomfort to the birds, which show this by being less active, by having their feathers ruffled, by loss of appetite, and by a more or less complete suspension of egg production. In a not inconsiderable number the eyes may become involved, while birds affected with roup are more or less prone to complicating diseases, among which pneumonia is the most fatal one.
>
> While the symptoms already described are usually attributed to roup, it is commonly very difficult to rule out the existence of the more damaging and

malignant canker. No hard and fast rules can be as yet established which would enable one to differentiate correctly between the two diseases. It is characteristic of roup to be confined to the nose and eyes, while commonly there is no evidence of such destructive changes in the affected parts as are marked by the formation of false membranes. The simultaneous presence of pock-like formations on the external skin should be regarded as sufficient to rule out simple roup.

The fundamental result of whatever infection produces roup is a reddened and injected mucous membrane of the section of the respiratory tract involved. When there is free drainage, as a rule nothing more is noted than an increase in the amount of mucus secreted. In those parts where the drainage is defective, like in the sinuses under the eyes, accumulations of a cheesy material may be found. This material is probably nothing else than pus, which in birds often assumes this form.

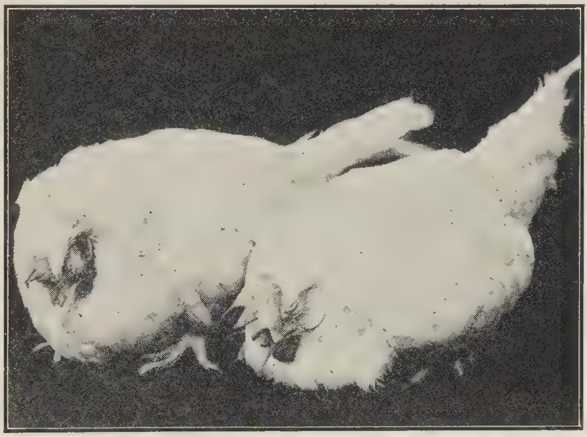

Fig. 167.—Typical appearance of fowls with nutritional roup, due to a deficiency of vitamin A. (*From Beach and Freeborn*, 1929.)

Roup has a tendency to persist in the affected birds for some time. When it remains confined to the nasal mucous membrane, the mortality among the more vigorous members of the flock is not a great one, but when it occurs in younger birds, during periods of cold, damp weather especially, the losses occasioned by the disease may be quite heavy. It is questionable whether losses can be materially reduced by any form of treatment, although there is no doubt that adequate treatment may save an occasional fowl.

If treatment is undertaken at all it should consist in a cleansing of the nostrils and the application of a mild antiseptic to the mucous membrane of the nose. A warm solution composed of 1 part of creolin and 200 parts of water may be injected into the nostrils, while the mouth is being kept open to permit the escape of the fluid.

This may be alternated by instilling into the nasal passages by means of an eye dropper a mixture composed of 5 gr. of carbolic acid, 10 gr. of menthol, and 1 oz. of liquid petrolatum. Treatment must be repeated two or three times a day and must be continued as long as nasal discharge is conspicuous.

Accumulations of cheesy matter in the sinuses under the eye are best removed by incisions through the overlying skin followed by pressing the mass through the wound made. After this the cavity can be washed out with the creolin solution mentioned above.

General sanitary conditions in the poultry house and protection of the birds against the inclemencies of the weather are important factors. As a roup case occurs in the flock, the affected bird should at once be removed, either to be kept in complete segregation, or to be used for the table, or to be destroyed or burned, as the judgment of the owner may dictate.

A disease popularly known as "nutritional roup" is described by Beach (1924) as being due to a deficiency of green feed in the diet. An adequate supply of vitamin A in the diet prevents the development of nutritional roup.

Tuberculosis.—Avian tuberculosis is a chronic infectious disease of great importance not only as a disease of chickens but also because it may be transmitted from chickens to other classes of live stock. The literature on avian tuberculosis is very extensive and those desiring further information than it is possible to give in this book should consult such references as Moore (1916), Calmette (1923), Van Es (1924) and Bushnell and Hinshaw (1925, 1925–1926).

Avian tuberculosis is caused by *Mycobacterium tuberculosis avium*, which may be introduced into a flock by the purchase of infected birds or by wild birds and other animals. The disease usually progresses slowly so that symptoms are for the most part observable only in adult birds.

In advanced stages of the disease there is loss in weight, dullness, dry appearance to the feathers, and diarrhea with greenish or yellowish droppings. On post-mortem examination the liver, spleen and intestines are covered with yellowish-colored tubercles of varying sizes.

Bushnell and Hinshaw (1925–1926) draw the following conclusions from their exhaustive study of the tuberculosis situation:

> Below we have outlined briefly the four most important places of infection on the farm. This will apply to other diseases as well as to tuberculosis.
>
> 1. Feed and water utensils not protected from droppings.
> 2. Dark corners and dust wallows under farm buildings.
> 3. Soil near the poultry house where birds are commonly fed. (The birds collect at these places even when no feed is being given and the soil in these areas become heavily contaminated.)
> 4. Wet yards with pools of stagnant water.
>
> It is usually quite a simple matter to correct these troubles.
>
> 1. Utensils may be carefully protected so that birds cannot get into them with their feet. They should be so arranged that they may be disinfected easily.
> 2. Birds may easily be prevented from getting under buildings.
> 3. Birds should not be fed in one spot continually.
> 4. If the runs cannot be drained, birds should be removed to new runs. At least mud holes can be filled in.

Another important method of preventing the introduction of disease into the flock is to purchase new birds only from disease-free flocks. All newly purchased birds should be placed in quarantine for at least two weeks before they are allowed to mingle with the flock. Such quarantine will not prevent the introduction of tuberculous birds unless the disease is well advanced, but will prevent the introduction of many other more acute troubles. A wise precaution would be to purchase birds subject to the tuberculin test. All new birds purchased for breeding purposes should be tested before they are sold and given a clean bill of health by a competent veterinarian.

1. Avian tuberculosis is very widespread in the country at the present time and is becoming more serious each year.
2. The disease is much more common in old than in young birds.
3. Experimental evidence seems to show that one type of the tubercle bacillus cannot easily be changed to another type, but that several species of animals may be affected by the same type.
4. Among the mammals, swine are most susceptible to avian tuberculosis, but many other animals may be infected.
5. The disease is transmitted from one bird to another almost entirely through the droppings. This mode of infection may be controlled to some extent by proper sanitation.
6. There are a few diseases which will be confused with tuberculosis in fowls. A differential diagnosis may be made in the laboratory or by use of the tuberculin test.
7. All tuberculous birds should be removed from the flock regardless of their value.
8. Diseased birds should not be placed on the market. They should be killed and burned.

Edema of the Wattles.—This is a disease which produces a local swelling of the wattles, caused by an organism similar to that of cholera. The wattles become filled with a dropsical fluid. The most practical way of dealing with the trouble is to cut off the wattles with sharp scissors and apply a dusting powder of equal parts of calomel and powdered burnt alum to prevent bleeding.

Favus.—This is a contagious disease commonly known as "white comb" because of the formation of grayish white spots on the comb, earlobes and wattles. The causative agent is a fungus called *Lophophyton gallinæ.* Apply tincture of iodine to the diseased areas.

Gout.—This disease is sometimes caused by excessive feeding of feeds rich in albumin, such as meat scraps, with the result that there is an abnormal quantity of uric acid in the blood. In advanced stages, the joints of the feet become swollen and painful. The disease is not of great economic importance but, if it occurs in a flock, the character of the feed should be examined and a dose of Epsom salts given, allowing one-half teaspoonful to each adult bird.

Leg Weakness or Rickets.—Leg weakness in chicks has been fully discussed on pages 300 and 356.

Limberneck.—Ptomaine poisoning and botulism sometimes give rise to paralysis of the neck of the chicken so that it is unable to raise its head. The trouble usually results from the chicken having eaten spoiled feed. For treatment, give Epsom salts, allowing one-half teaspoonful per bird.

Polyneuritis.—This nutritional disease has been discussed on page 300.

Tumors.—Hens in a heavy laying condition are more inclined to develop tumors than other chickens but skin and bone tumors sometimes occur on any of them, tumors in laying hens being for the most part ovarian tumors. In most cases successful treatment is impossible.

Vent Gleet.—This is an infectious, venereal disease which causes inflammation in the cloaca and vent, which usually appears red and swollen and emits a very offensive odor. The disease is readily spread from female to female by the male. Treatment is usually useless and all diseased birds should be killed and burned.

INJURIES, BAD HABITS AND POISONING

There are injuries that sometimes cause losses among chickens and there are bad habits and poisoning that cause mortality. These are discussed very briefly.

Bumblefoot.—This condition usually develops from bruises causing a swelling of the foot, inflammation sometimes developing. Remove the cause, such as excessively high roosts from which birds have to jump to the floor. Apply tincture of iodine daily or if the foot is badly swollen, it may be lanced and the contents cleaned out thoroughly, after which apply tincture of iodine or a 5 per cent solution of carbolic acid.

Egg Bound.—The egg-bound condition may result from a stoppage of the oviduct by a tumor or stricture or sometimes the egg is too large to pass through the cloaca.

> The surest method of treatment is to remove the egg by the following procedure: Pass the forefinger through the vent. With the other hand pressing on the abdomen of the fowl force the egg toward the vent, guiding it by the aid of the inserted finger. When the shell is observed through the vent puncture it with an awl or other sharp-pointed instrument, break it in pieces, and withdraw these and the egg contents. Isolate the bird and inject cold water into the cloaca (the common passage into which the intestine and the oviduct open) to reduce the inflammation. If the oviduct has been everted through the vent, clean and push the parts back and inject cold water frequently until the tissues remain in place (Gallagher, 1927).

Egg Eating.—Occasionally many eggs are lost through the bad habit of egg eating developing in the flock. The trouble may start from eggs being accidentally broken in open nests or one or more hens may deliberately break an egg in the nest or on the floor. When once the trouble begins it is frequently hard to check. The best preventive measure is to have partially darkened nests, where the hens enter the nests from the rear and there is a door in front of the nests for collecting the eggs, as illustrated in Fig. 133 on page 285.

Feather Pulling.—This vicious habit is more apt to appear in chicks reared in confinement and in laying hens kept in confinement than in chicks reared on range and laying hens allowed access to yards. The exact cause of the practice of feather pulling has never been determined, although it rarely occurs in flocks given range. Kennard (1928) offers the following suggestion as a control measure:

> Removal of the tip of the upper beak is undoubtedly most effective for the control of feather pulling and other forms of cannibalism. This treatment renders a bird harmless for a time so far as these vices are concerned. The tip of the beak is removed to the quick so that it is tender for a while and leaves it in such shape that it is impossible for a bird to firmly grasp either feathers or flesh. Tipping the beak if properly done involves little pain or discomfort to the bird and seldom causes any bleeding. About three weeks is required for the beak to grow out again. During this time the birds usually forget their past vices and no further trouble results. In some cases where the vice has become chronic, subsequent treatments may be required. Tipping the beak appears not to interfere with the bird's eating an all-mash feed or to affect her egg production.
>
> Like most procedures there is a right and wrong way, and in this case the right way is easy and simple and the most effective. The edge of upper beak is cut in about ⅛ in. and ⅛ to $\frac{3}{16}$ in. from the tip, depending on size of beak and length of tip. Then by prying and pulling with flat side of knife the point of beak is removed by tearing and not by cutting. The small cut serves only to get a hold and start the tearing. By tearing the beak it can be removed much closer to the "quick" without bleeding and it is so much easier than paring, even with a razor-edged knife. After the tip is torn loose one should pull down toward the lower beak to remove the lower knife edge of the other side opposite where the starting cut was made. This gives the removed tip a V-shape and prevents a bird from getting a firm grasp of a feather or flesh. After a little practice beaks can be removed at the rate of 200 to 225 an hour when one has a helper to handle the birds.

Frozen Combs and Wattles.—In northern parts of the country frozen combs and wattles are very common occurrences. Payne and Ingram (1927) observed that the freezing of the combs on breeding males reduced fertility and hatchability below normal for a period of 11 days.

If treatment is decided upon, first, thaw out the comb and wattles by rubbing them with the fingers well smeared with vaseline. Then, use a mixture of 5 parts vaseline, 2 parts glycerin and 1 part turpentine, applying the mixture once or twice daily. Keep the birds in a cool place.

Impacted Crop.—This condition is usually due to a large amount of coarse grass or other fibrous material becoming lodged in the crop. Sometimes the material may be removed by giving the bird a teaspoonful or more of sweet oil and massaging the crop and lower part of the gullet while the bird is held head downward. In other cases it is necessary to open the crop and remove the contents with a spoon or other instrument. Wash the crop out with warm water and sew up the wall of the crop. Use coarse, white silk thread; tie each stitch separately, being sure not to sew the wall of the crop and the skin together. After the wall of the crop is sewn up, then sew up the skin.

Prolapsis or Eversion of the Oviduct.—This condition, popularly known as "blowout," is the result of a portion of the oviduct extruding through the vent. The cause is not definitely known, although the trouble occurs much more frequently in laying flocks kept in confinement than in those given range.

Sometimes the trouble causes heavy mortality. Kennard (1928) has observed that when one case occurs, if it is not removed immediately, a number of hens soon start picking at the oviduct and then soon learn to pick at other hens with the result that there are numerous "pickouts" in the flock. It is obvious, therefore, that affected birds should be removed from the flock at once. Kennard's suggestion on tipping the beak to prevent feather pulling also applies here. Some poultrymen have found that increasing the proportion of corn meal in the laying ration is of some help.

Toe Pecking.—This bad habit sometimes develops in flocks of chicks a few days old, especially if they are kept confined. If pecking succeeds in drawing blood, the habit is liable to spread quickly. Remove all chicks that have had their toes pecked as soon as they are observed. Sometimes if the brooder room is kept partially darkened there is less danger of the habit spreading. Letting the chicks out on range nearly always effects a cure. If chicks cannot be given range, then provide plenty of hopper space. Injured toes may be painted with pine tar.

Rose-chafer Poisoning.—In growing chickens up to 10 weeks of age there is sometimes heavy mortality resulting from eating rose chafers, which are also referred to as "rose bugs" and "rose beetles." Rose chafers are frequently found in abundance during June and July in vineyards, or where there are daisies, certain flowering shrubs and birch trees.

Only a few beetles are necessary to cause death and, according to Lamson (1922), death usually occurs within 24 hr. Old hens, however, are not killed, even when large numbers of the rose chafers are eaten. In order to prevent losses from rose-chafer poisoning, the chickens should be kept away from places infested with the chafers.

INTERNAL AND EXTERNAL PARASITES AND THEIR CONTROL

There are numerous internal and external parasites affecting chickens that cause enormous losses through mortality, retarded growth in young stock and a decrease in egg production among laying hens. Most of the parasites multiply rapidly at certain seasons of the year and unless they are kept in check they may be the cause of serious losses. Practically all the parasites can be kept in check quite readily, however, through rigid sanitation on the poultry plant.

For information on the life histories of the various parasites and methods of controlling them, readers are referred to the following: Stubbs and Crawley (1922), Pearl, Surface and Curtis (1923), Hall (1925), Bishop and Wood (1926), Ackert (1927), Cram (1927, 1928*a*, 1928*b*) and Baker, Conklin, Maw and Fogerty (1928–1929).

INTERNAL PARASITES

Ackert's work has furnished reliable information that the damage done to young chicks by the large roundworm of the intestines is very extensive. Studies by Jones of the U. S. Bureau of Animal Industry have demonstrated that ground beetles and dung beetles, some of them being very small forms, may act as intermediate hosts of various poultry tapeworms and control measures must be of such a nature as to exclude such insects. Cram, also of the Bureau of Animal Industry, has shown that the number of species of roundworms which are injurious to poultry is much greater than was formerly thought and that grasshoppers are the intermediate hosts of at least two of these roundworms.

Since Graham and McCulloch (1929) give a practical discussion on the prevention of intestinal worms in chickens, their more important observations are given here:

> Chickens are affected by two general types of intestinal worms—roundworms and tapeworms.
>
> **Roundworms.**—The large roundworm is 3 to 4 in. long and is found in the intestine. The small roundworm lives in the ceca, or blind pouch, and is less than ½ in. in length. These worms do not attach themselves to the intestinal wall or to the ceca. Both types of roundworm resemble earthworms in shape.
>
> Tapeworms are flat, segmented, ribbon-like organisms. They cling to the wall of the small intestine. Several species are found in chickens. They vary in length from several inches down to microscopic forms; in fact some are so small as to appear as whitish pinpoint specks on the lining of the intestine.
>
> All intestinal worms are harmful. The injury they do depends largely on the degree of the infestation and the length of time the fowls have harbored the parasites. Chronically infested chickens may show pronounced worm symptoms and serious inflammatory changes in the intestines though relatively few worms may be present. In the absence of worms a parasitic enteritis in fowls may be easily confused with other diseases characterized by inflamed intestines.
>
> The damage that a small number of intestinal worms can do by lowering the vitality of the flock is often underestimated. Reduction in egg yield or loss of flesh as a result of worm infestation may often escape attention until the flock

is badly infested. Because worm infestation is not recognized, losses directly traceable to intestinal worms may appear secondary in importance to those resulting from contagious diseases. However, lowered vitality from worm infestation often paves the way for the other diseases. Worm infestation may be the forerunner of fowl cholera and fowl typhoid, while increased susceptibility to colds, bronchitis, chicken pox, and roup are not infrequently traceable to worm infestation. Worms may also serve as inoculating agents and aid in the spread of blackhead and other contagious diseases.

The prevailing opinion that intestinal worms do the greatest damage through absorption of food is not confirmed by observations in infested flocks. Loss of nutrients, although a factor, is secondary to enteritis. The inflamed and thickened intestine is incapable of normal digestion and assimilation of food. Proof of the injurious effect of worms is commonly observed in fowls that fail to improve in condition following the treatment and expulsion of the worms. In such cases the intestinal injury is well-marked.

Poisons produced by worms in the digestive tube are absorbed along with other poisons from the intestines. One of the poisons manufactured by worms appears capable of destroying the red blood cells and producing symptoms of anemia. Affected chickens are pale about the eyes, comb, and wattles. Another poison generated by worms affects the nerve centers that control motion. The symptoms produced include lameness, drooping wings, lack of coordination of movements, paralysis, wryneck, and blindness. A specific disease characterized by paralysis should not be confused with paralysis associated with worms, coccidiosis, internal tumors, and vitamin deficiencies.

Roundworms develop from microscopic eggs less than one three-hundredth of an inch in diameter. The eggs are laid by the female worm in the intestine of infested fowls and are passed from the intestine in the droppings in large numbers. When moisture and temperature conditions are favorable, a small embryo, or larva, develops in the worm egg. Only when the egg reaches the embryo stage is it infective; non-embryonated eggs taken in with food and water are incapable of causing roundworms. Winter weather or lack of moisture will delay egg development to the infective stage, but the eggs will remain dormant and continue their development when moisture and temperature conditions become favorable. Owing to the thick egg capsule, neither freezing nor ordinary disinfectants destroys them.

Tapeworms.—Tapeworms, unlike roundworms, require an intermediate host in which a period of their development takes place. Not all the intermediate hosts of fowl tapeworms are known. Those recognized include house flies, earthworms, and snails. The development of tapeworm eggs in the intermediate host is necessary; without this host tapeworm eggs do not reach the infective stage.

A majority of the chicken tapeworms can be distinguished from roundworms by their flattened, segmented character, together with the fact that they are firmly attached to the lining of the intestines. The terminal segments of the mature tapeworm (3 to 20 in all) are complete units, capable of reproduction. Tapeworm segments containing eggs are passed in the droppings, and if consumed by house flies, earthworms, or snails, certain stages of their development take place. After existing for a time as cysts in one of the intermediate hosts, the larva grows to maturity. When the infested intermediate host is eaten by fowl, the larva of the tapeworm is released from the egg and attaches itself to the lining of the intestine. Here it completes the life cycle by developing into the segmented worm.

To prevent tapeworm infestation of a flock, the life cycle of the parasite must be broken at some point. This may be done by preventing the accumulation of chicken manure and other filth, which constitute the breeding places of the intermediate hosts. Screening of poultry houses to control flies is also recognized as a preventive measure. Since earthworms and snails become infested through eating the droppings of infested fowls, rotation of lots, plowing, and cultivating will reduce this source of danger.

Worm Control.—Important contributing factors in the spread of intestinal worms in poultry are overstocking and the common practice of providing free range of the barnyard or the use of ground without proper rotation and cultivation. Infested ground is chiefly responsible for perpetuating the worm problem on many farms. Keeping chickens on the same ground year after year favors the development of intestinal parasites irrespective of the size of the flock. The smaller the area the greater the danger. Small flocks with unlimited range suffer less from worms than large flocks. Backyard flocks with limited range are commonly infested.

Chickens under six months of age are more susceptible to worm infestation than mature fowls. Symptoms of unthriftiness and rapid loss of flesh generally end in death. Over a longer period of time, similar symptoms appear in mature fowls.

The most economical way to combat worms in poultry is by practicing the essentials of simple sanitation. Swine growing has been revolutionized on many farms in the Middle West by simple sanitary measures. Poultry sanitation properly applied is quite as efficient in checking worm infestation in fowls.

Preventive measures for controlling roundworms in poultry are not entirely effective for tapeworm infestation but the general procedure is the same. Breeding places of flies and other insects should be destroyed. Accumulations of chicken manure should be avoided, and if necessary, flies kept out of chicken houses by screening. The danger from earthworms and snails, which act as intermediate hosts for the tapeworm can be reduced by rotating lots and plowing and cultivating the land on which the chickens run.

Results obtained in worm control are generally in keeping with the efficiency of the sanitary conditions. Short cuts or makeshifts should be avoided. The objective is to keep the worm eggs in the droppings of diseased birds from contaminating the feed and water. This simple precaution enables owners to check the spread of worm infestation. The following measures are being successfully employed by many flock owners in Illinois in cooperation with the Agricultural Extension Service of the University.

Poultry houses should be cleaned once a week and dropping boards daily. Concrete runs for young stock have the advantage of being easily cleaned and disinfected, thus eliminating all worm eggs before they become infective. Poultry houses should have concrete or board floors with removable dropping boards under the roosts. The houses should be disinfected once a month. Remove and burn all dirt and droppings. Scrub the floor, side walls, roosts, and dropping

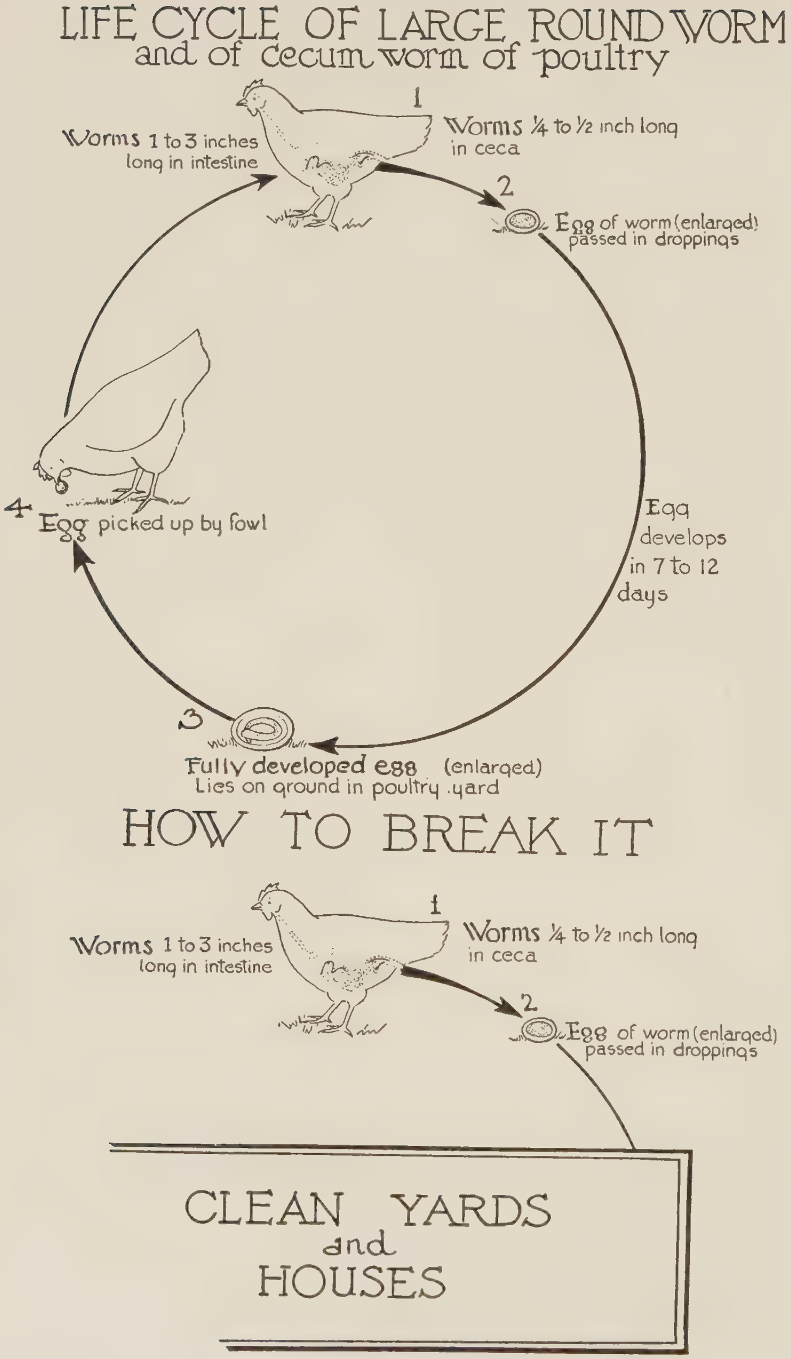
LIFE CYCLE OF LARGE ROUND WORM
and of cecum worm of poultry
1
Worms 1 to 3 inches long in intestine
Worms ¼ to ½ inch long in ceca
2
Egg of worm (enlarged) passed in droppings
Egg develops in 7 to 12 days
3
Fully developed egg (enlarged)
Lies on ground in poultry yard
4
Egg picked up by fowl
HOW TO BREAK IT
1
Worms 1 to 3 inches long in intestine
Worms ¼ to ½ inch long in ceca
2
Egg of worm (enlarged) passed in droppings
CLEAN YARDS and HOUSES

FIG. 168.—Proper sanitation is an important factor in controlling round worms and ceca worms. (*Modified from original by U. S. Dept. Agr.*)

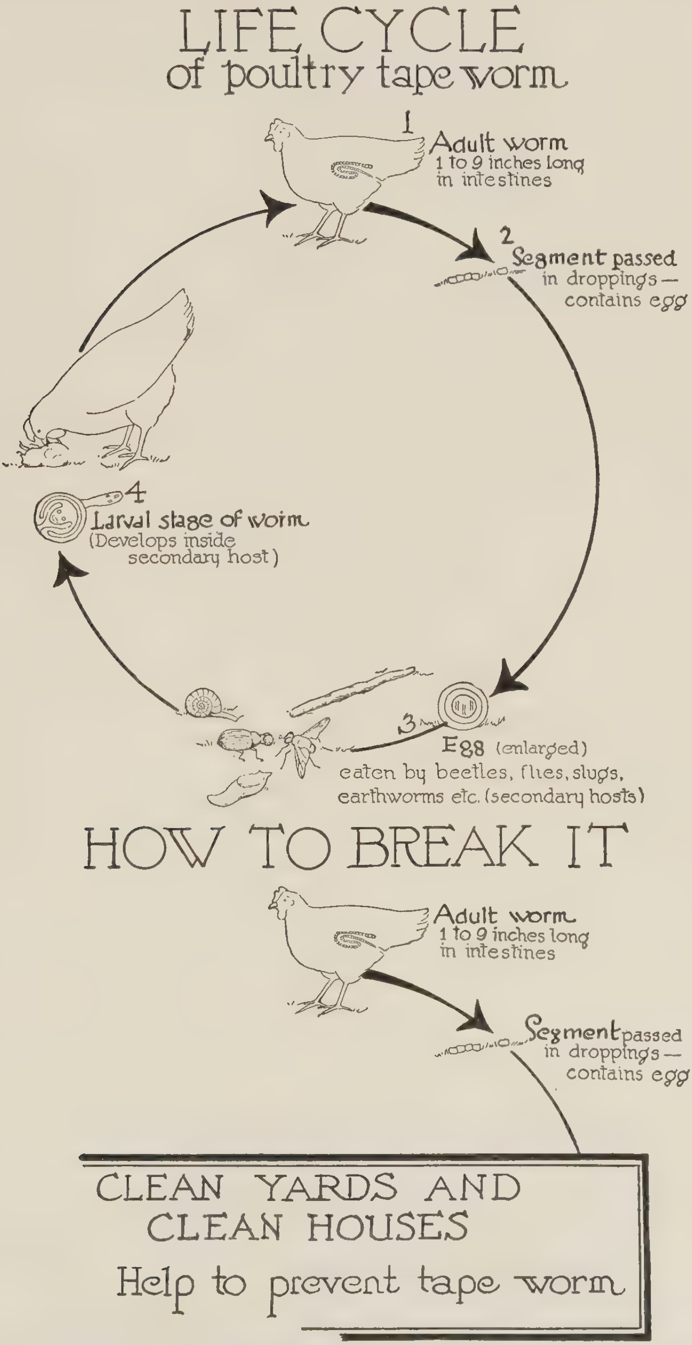
LIFE CYCLE
of poultry tape worm
1
Adult worm
1 to 9 inches long
in intestines
2
Segment passed
in droppings —
contains egg
3
Egg (enlarged)
eaten by beetles, flies, slugs,
earthworms etc. (secondary hosts)
4
Larval stage of worm
(Develops inside
secondary host)
HOW TO BREAK IT
Adult worm
1 to 9 inches long
in intestines
Segment passed
in droppings —
contains egg
CLEAN YARDS AND
CLEAN HOUSES
Help to prevent tape worm

Fig. 169.—Sanitation is an important factor in controlling tapeworms. (*Modified from the original by U. S. Dept. Agr.*)

boards with a solution consisting of 1 lb. of lye to 40 gal. of boiling water. After cleaning, use a reliable disinfectant to spray the roost, floors, and walls.

Brooder houses should be cleaned and disinfected, and placed on fresh ground for chicks. The floor should be cleaned once a week and oftener if disease appears.

Provide clean water and clean feed by using sanitary feed and water containers. Keep the houses dry and well ventilated.

Confine all mature fowls to a limited range area and do not allow them to run with other live stock. Also keep the young chickens in confinement, either on concrete runs or on a clean range of fresh grass, clover, or alfalfa, over which no chickens of any age have run the previous year. Provide extra range lots each year so that the unoccupied lots can be planted and cropped. Worm control on the range can be accomplished by rotating the yards. Fresh ground is better than medicine in preventing worm infestation.

Simple fundamentals of poultry sanitation have enabled many owners to raise young stock relatively free from intestinal worms and to maintain healthy flocks. Giving remedies on suspicion in undiagnosed poultry diseases often proves an expensive practice. Medicines do not destroy the worm eggs, which are the fountain head of worm infestation; these must be eliminated by providing poultry with sanitary surroundings. Medicines, furthermore, may provide the owner with a false sense of security and lead him to neglect essential sanitary measures. If medicinal remedies seem advisable, those with the least danger should be selected. Worm medicines in overdoses are poisonous to the fowls. The poisonous properties which make them effective in expelling the worms should not be disregarded.

A correct diagnosis is the first essential in treating any illness. Since worm symptoms are often obscure and indefinite, it is best to consult a qualified veterinarian in diagnosis and treatment for temporary relief in diseased flocks.

Roundworm remedies are given in feed or by individual treatment. Oil of Chenopodium, carbon tetrachlorid, tetrachlorethylene, and nicotine sulfate are given in capsules or with a rubber tube, a syringe, or a funnel. The dosage depends upon the weight of the fowl. In badly infested flocks individual treatment should be repeated in 5 to 10 days. Feed should generally be withheld for 12 to 24 hr. before the treatment is given. Worm medicine should be avoided in hens in high egg production.

The mixing of roundworm remedies in the feed is not entirely satisfactory. Mass treatment eliminates the necessity of catching and dosing each chicken separately, yet it does not insure proper dosage. When flock treatment is given, tobacco dust containing 1½ to 2 per cent of nicotine may be used. One pound of tobacco dust should be mixed with 49 lb. of dry mash. The tobacco mixture should be fed to pullets only every other week. The treatment may be continued for several months; in mature fowls, however, egg production may be reduced if tobacco is fed longer than 6 months or if an overdose of nicotine is given. As the tobacco loses its potency upon exposure to the air, it should be mixed with the mash in quantities that may be consumed within a week.

Kamala in capsules is employed for individual treatment of fowls infested with tapeworms. It is not necessary to starve chickens before giving kamala capsules. Care must be used in giving the treatment, since overdosing is harmful.

Lye is sometimes used for tapeworms. The lye-grain mixture may be prepared by adding 1 tablespoon of lye to 1 gal. of wheat and oats mixed. Cover the mixture with water and boil for 1 hr. Stir the mixture and replace the water to prevent burning. Allow the mixture to cool and feed it to fowls after they have been starved for 24 hr. During the feeding of the mixture, supply plenty of fresh water.

All fowls treated for worms should be confined in a house. If starved during the day and treated in the afternoon, the dropping boards should be cleaned the next morning and the refuse burned in order to destroy the eggs and worms. If the treatment is applied early in the day, straw should be spread over the floor so that expelled worms and eggs can be removed and burned. Treatments may be repeated after several days, but permanent results seem dependent upon the adoption of a definite system of poultry sanitation.

Coccidiosis.—Heavy mortality sometimes results from coccidiosis, especially in young chicks up to two months of age. The disease is caused by a very small protozoan organism, which multiplies very rapidly in the intestines of diseased chickens. Tyzzer (1929) has identified four species of coccidia: *Eimeria tenella, Eimeria mitis, Eimeria acervulina and Eimeria maxima.* Large numbers of the organisms are discharged in the droppings and the transmission of infection takes place by healthy birds coming in contact with feed, water and soil contaminated with the organisms.

The usual symptoms of the disease are dullness and diarrhea. The chicks may retain their normal appetites for a considerable time although they usually lose weight. Adult birds possess considerable power of resistance to the organism but may harbor the disease in chronic form.

If treatment is decided upon, the advice of Gallagher (1927) should be followed.

> The following medicated drinking water, given in glass, glazed-ware or enamelware receptacles (not uncoated metal ware) has given beneficial results in the treatment of coccidiosis in young chickens; it should be supplied continuously until the birds are 3 months old or the disease has disappeared:

	Grains
Corrosive sublimate	6.0
Citric acid	3.0
Calcium sulphocarbolate	7.5
Sodium sulphocarbolate	7.5
Zinc sulphocarbolate	15.0
Water, 1 gallon	

Under ordinary circumstances, however, the treatment of diseased birds is out of the question. Everything possible should be done to prevent the appearance and spread of the disease. Rigid sanitation is the best preventive measure. Charles (1921–1922) says that "careful and thorough sanitation of the poultry houses and yards is one of the most effective ways of preventing trouble from coccidiosis."

Special feeding methods are recommended as a preventive measure. Beach (1925) found that the effect of feeding cultures of *Bacillus Acidophilus*, lactose, dry skim milk or whole milk was to increase the hydrogen-ion concentration of the contents of the ceca of chickens, a condition that seems to provide resistance against invasion by the organism. Beach and Davis (1925*a*) observe: "The fact that feeding chickens mash containing 40 per cent dry skim milk not only protected them against coccidial infection, but also stimulated rapid growth indicates that this would be a valuable practice in the prevention and control of outbreaks of the disease on poultry farms." Sherwood (1925) found that the feeding of condensed buttermilk materially decreased the mortality of chicks that were artificially infected at 11 and 12 days of age. Tyzzer

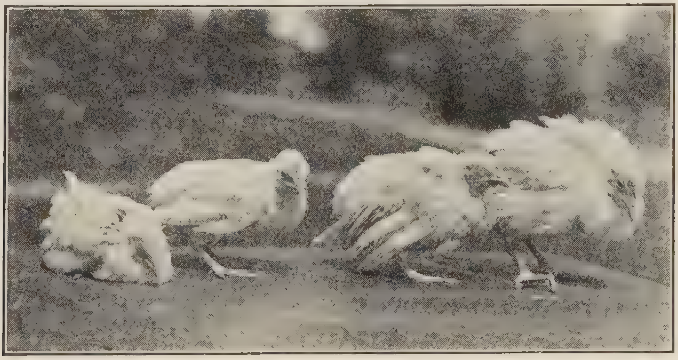

Fig. 170.—Chicks infected with coccidiossis. (*From Sawyer and Worley*, 1927.)

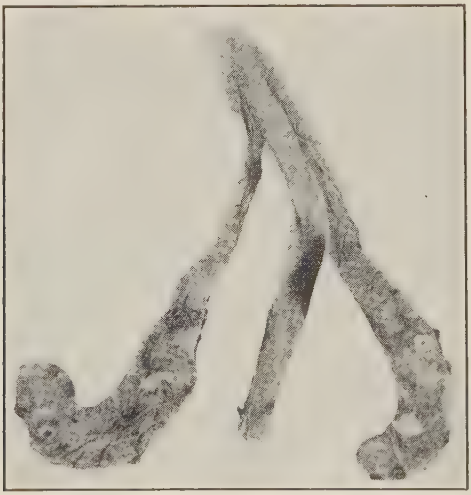

Fig. 171.—Ceca of chick with coccidiosis. (*From Beach and Freeborn*, 1929.)

(1929), however, believes that not only does the feeding of rations relatively high in milk content not prevent coccidial infection but may actually be injurious to the chicks.

Black (1928) urges sanitation as the most effective method of control:

> After the disease has appeared in the flock, the greatest factor is sanitation, and the poultryman practicing brooding in confinement has the advantage. Under these conditions the chicks are confined to a small area which can be cleaned. Since it is known that the oocyst will develop to the infective stage in 4 days under favorable conditions, and that a reinfestation is sure to occur if the parasite is not destroyed, the logical procedure is to remove the source of infection. Chicks brooded on range should be confined to the house while the disease is in evidence.

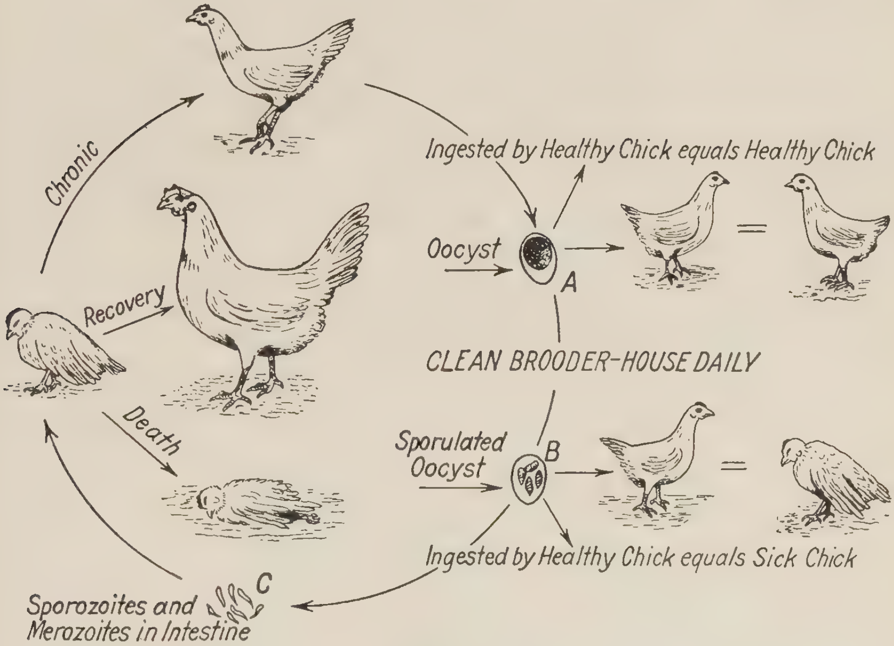
Chronic
Recovery
Death
Ingested by Healthy Chick equals Healthy Chick
Oocyst
A
CLEAN BROODER-HOUSE DAILY
Sporulated Oocyst
B
Ingested by Healthy Chick equals Sick Chick
Sporozoites and Merozoites in Intestine
C

FIG. 172.—The life cycle of the coccidiosis parasite. Under favorable conditions the entire life cycle of the parasite which causes coccidiosis may be completed in from eight to ten days. In the egg stage it gets into the intestinal tract by means of contaminated feed and water. (*Calif. Agr. Exp. Sta.*)

> The houses should be cleaned at least every third day, although every day would not be too often in the early stages of the disease. A small amount of fine litter that will readily absorb moisture should be used to facilitate cleaning, and a little lime scattered over the floor after the litter has been removed will help keep the house dry. The use of medicinal agents either in the prevention or cure of this disease has been found unsatisfactory.

The practical importance of sanitation is emphasized by Gildow and Wisnicky (1928) in the following terms: "Sanitary measures are vital factors in the treatment of birds for coccidiosis. The removal of litter and absolute cleanliness in feed and water containers are essential, since the organisms incubate and are capable of producing the disease three to seven days after they have been discharged. Every precaution possible should be taken to keep the chickens out of the feed and water since their feet are usually covered with the organisms." Tyzzer (1929) concludes that cleanliness, a highly nutritional diet and the avoidance of overcrowding are the important control factors.

Johnson (1927) emphasizes the importance of resistance of the chicken to coccidial infection and says:

> Knowing that coccidial infection produces resistance provides a possible standard of evaluating the success of coccidiosis control methods. Fowls reared under conditions permitting considerable coccidial infection should be highly resistant, while with the reverse true, marked susceptibility would be expected. The value of the highly artificial methods of brooding and rearing being developed and recommended at present for the control of coccidiosis cannot be determined without studying their relation to the resistance problem.

Gapes.—This is a disease affecting young chicks, causing them to gape for breath. The causative agent is a parasitic worm, *Syngamus trachea,* which attaches itself to the inside of the windpipe. Treatment of diseased chicks is difficult. Rear chicks on clean ground and since turkeys harbor gapeworms, chicks and turkeys should never be reared together.

EXTERNAL PARASITES

The control of lice and mites is discussed in a very practical way by Beaudette (1929), his observations being as follows:

> **Lice.**—Over 40 species of *mallophaga* (bird lice) are known to attack common domesticated birds. Lice are readily distinguished from the other external parasites by the fact that the body is divided into head, thorax, and abdomen. Furthermore, lice have three pair of legs. The mouth parts are strong and fitted for cutting and biting. Lice spend their entire life upon the host and leave only to migrate to another host. When the host dies they will remain on the host for some time. The eggs (nits) of the female are deposited on the feathers, and hatch in about a week. The young reach maturity in about two weeks.
>
> The head louse (*Lipeurus heterographus*) is so named because it is found about the head and neck. It is probably the most injurious species to young chicks.
>
> The wing louse (*Lipeurus variabilis*) although resembling the head louse is smaller and somewhat narrower. It is found especially under the primary feathers of the wings.
>
> The fluff louse (*Goniocotes hologaster*) is not considered of much importance.
>
> The large hen louse (*Goniocotes abdominalis*) is less abundant than the fluff louse and is easily recognized by its large size and its smoky gray to blackish markings.

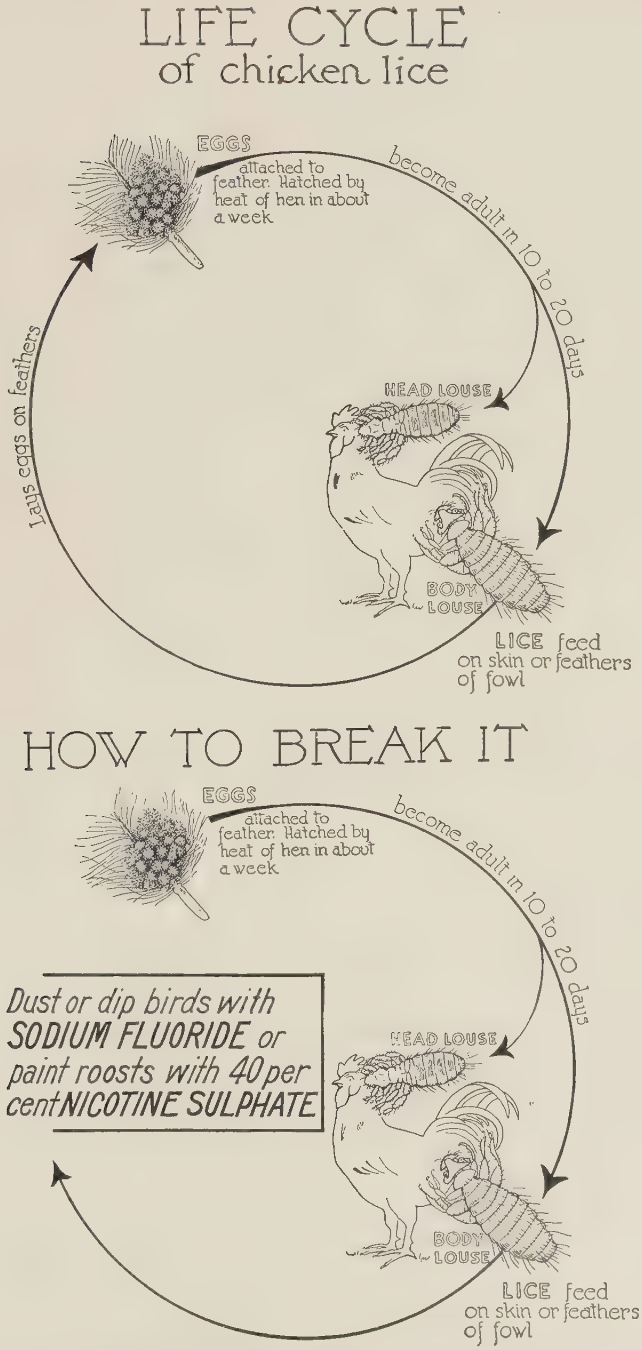
LIFE CYCLE
of chicken lice
EGGS
attached to feather. Hatched by heat of hen in about a week
become adult in 10 to 20 days
HEAD LOUSE
BODY LOUSE
LICE feed on skin or feathers of fowl
Lays eggs on feathers
HOW TO BREAK IT
EGGS
attached to feather. Hatched by heat of hen in about a week
become adult in 10 to 20 days
HEAD LOUSE
BODY LOUSE
LICE feed on skin or feathers of fowl
Dust or dip birds with SODIUM FLUORIDE or paint roosts with 40 per cent NICOTINE SULPHATE

Fig. 173.—Lice are easily controlled by dusting or dipping the birds individually with sodium fluoride or by painting the roosts with nicotine sulphate. (*Adapted from original by U. S. Dept. Agr.*)

The small body louse (*Menopon pallidum*) is light in color and smaller than the large head louse. Its habits are also similar.

The common large louse of the hen (*Menopon biseriatum*) is perhaps the most common species. It stays close to the skin and moves rapidly.

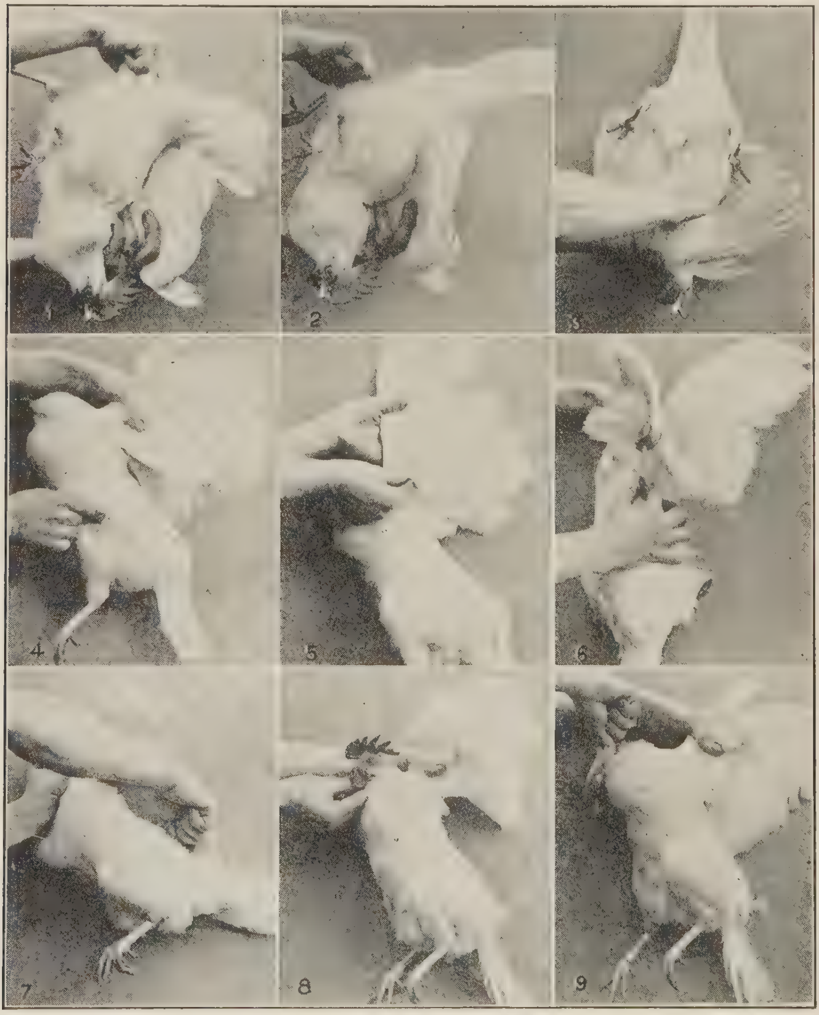

Fig. 174.—Method of holding the fowl and points at which sodium fluoride is applied when using dust method. Note that each figure shows the bird held in the same manner. The following is the order of application: (*a*) base of tail, 1; (*b*) below the vent, 2; (*c*) to one side of keel bone, 3; (*d*) other side of keel bone; (*e*) outside thigh region (left), 4; (*f*) along wing (left), 5; (*g*) on back, just back of wings, 6; (*h*) base of tail, 7; (*i*) outside thigh region (right); (*j*) along wing (right); (*k*) throat, 8; (*l*) back of head, 9. (*Photograph by Western Wash. Exp. Sta.*)

The treatment of lice is discussed as follows:

Since lice are found almost entirely upon the host, it is obvious that treatment should be directed largely to the host. Although danger of reinfestation from the litter and fallen feathers is not great, a thorough cleaning of the house and burning of the litter is desirable. Other things being equal, treatment should be applied at the time of the year when the fewest birds are kept. It is highly desirable, however, to have the premises clean when young chicks are hatched. Finally, if the treatment employed is not sufficiently powerful to kill the eggs of lice, a second treatment should be applied about ten days to two weeks after the first, in order to kill the newly hatched. Also, it is very important to treat every bird in the flock if the treatment is an individual one. One untreated bird may serve to reinfest the entire premises.

The use of various dusts is discussed as follows:

Sulphur.—A finely ground product should be used. One thorough dusting is said to be sufficient. About 6 lb. of sulphur are sufficient for the treatment of 100 birds.

Sodium fluoride is applied by the so-called "pinch method"; that is, a pinch is put on the breast, on each thigh, below the vent, on each side of the back, on the neck, on the head, and finally on the underside of each outspread wing.

When the "pinch method" is used, 7 lb. of fluoride is sufficient for the treatment of 100 birds. The action of this agent is slow and it will not kill eggs, but enough dust should remain in the feathers to kill the newly hatched lice. Contrary to the usual statement, this agent may be quite irritating to the mucosa of the respiratory tract and the skin of the operator, if the skin becomes moistened with perspiration.

Lowry Powder.—Three parts of gasoline and one part of crude carbolic acid (90 to 95 per cent) are mixed. To this, plaster of paris is added slowly while mixing until all of the liquid has been taken up. Usually four parts of powder are required to absorb one part of liquid. The result should be a slightly moist product.

Sodium Fluosilicate.—This may be used in the same way as sodium fluoride.

Dust Bath.—This may be made by mixing one part of sodium fluoride with three parts of road dust and placing the mixture in a box to which the birds have access. Instead of this, one part of sodium fluosilicate may be mixed with three parts of finely ground phosphate rock.

Beaudette discusses the use of dips in the following terms:

Sodium Fluoride.—One ounce of the commercial or three-fourths ounce of the C. P. product is added to each gallon of tepid water contained in a wooden bucket. The wings of the bird are held in one hand, the feet in another, and the bird is submerged for about half a minute. After the bird is drained the head is next submerged. Sodium fluosilicate may be used to replace the fluoride.

Soap Solution.—An ounce of laundry soap is dissolved in a gallon of water. This treatment does not kill the eggs and must be repeated in ten days to two weeks.

Kerosene Emulsion.—One-half pound of soap is dissolved in one gallon of hot water. After this is removed from the source of heat, two gallons of kerosene are added and thoroughly mixed. Three gallons of this stock emulsion are added to nine gallons of water to make a mixture suitable for dipping.

Dips should be used only in warm weather when there is no breeze. The operation should be stopped early enough in the day to give the birds a couple of hours in which to dry before the sun goes down.

Ointments may be used in certain cases:

Carbolated Petrolatum.—This agent is quite satisfactory for head lice in young chicks.

Lard may be used on the head and under the wings of baby chicks.

Mercury Ointment.—One part of mercurial ointment is mixed with two parts of petrolatum. A piece of ointment the size of a pea should be applied beneath the wings and around the vent and rubbed in well to prevent poisoning. One application is said to be sufficient for complete extermination of all lice.

One of the most practical methods of controlling lice is by the use of nicotine sulfate:

A nicotine sulfate solution containing 40 per cent of nicotine is painted on the roosts. The application should be made just before the birds go to roost. Treatment should be applied to all places where birds are apt to roost. Three or four drops of the liquid also should be put in each nest. The house should not be tightly closed as birds have been known to die as a result of poor ventilation. A second treatment should be applied in ten days to two weeks. This is the most desirable treatment available.

Mites.—There are many species of mites and the habits of each vary accordingly. Some are very destructive, others may be of little consequence. Unlike lice, mites have four pairs of legs and the body is not divided as it is in lice.

The common chicken mite (*Dermanyssus gallinæ*) is also referred to as the "roost mite." When engorged with blood the parasite is of a reddish color and is referred to as the "red mite." These pests visit their prey at night. Only a few are to be found on the birds during the day. When one finds "salt and pepper markings" (the droppings of mites) on the roosts, an examination of the cracks and crevices in the house will reveal myriads of these pests. This species is very undesirable and may cause a high mortality in young chicks. Soon after engorgement the female deposits 3 to 7 eggs and after another feeding the process is repeated so that finally about 30 eggs are laid. Mites live for long periods and are easily transmitted to new premises on coops, bags, and clothing.

Treatment should be directed to the cracks and crevices. Remove and burn all litter. Several agents may be used, but a thorough application should be made of whichever is chosen. Wood preservers having anthracene oil as a base are most commonly used. These should be diluted one-half with kerosene to insure a proper consistency for spraying. Crude oil similarly diluted may be used but it is not readily taken up by the wood and may remain to soil the feathers of the birds. Pure kerosene or kerosene emulsion in double strength will destroy all mites with which it comes in contact, but several applications are necessary. Arsenical dips such as those used for cattle ticks, lime-sulphur solutions or whitewash containing 5 per cent of crude carbolic acid, are also applicable, but several applications are necessary.

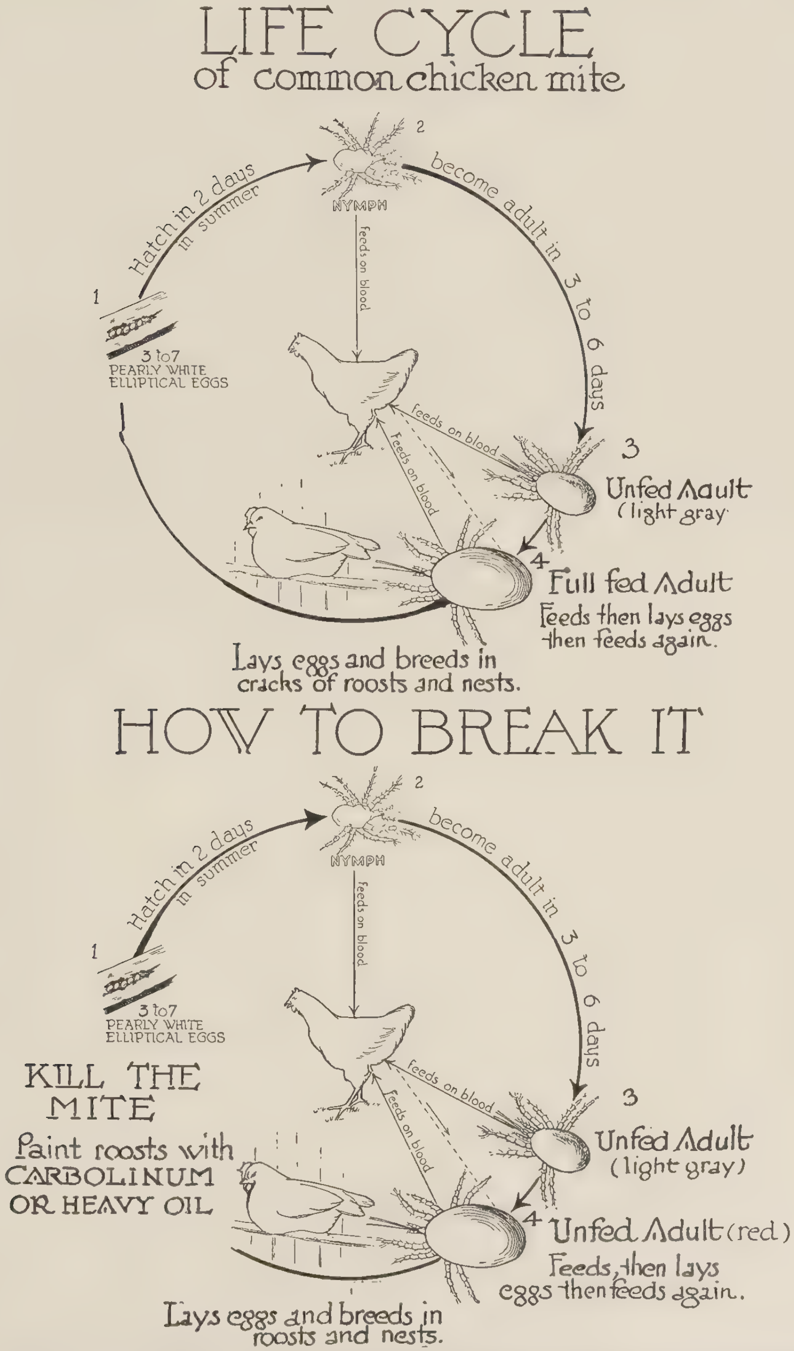
LIFE CYCLE
of common chicken mite
1
3 to 7
PEARLY WHITE
ELLIPTICAL EGGS
Hatch in 2 days
in summer
2
NYMPH
feeds on blood
become adult in 3 to 6 days
3
Unfed Adult
(light gray)
feeds on blood
Feeds on blood
4
Full fed Adult
Feeds then lays eggs
then feeds again.
Lays eggs and breeds in
cracks of roosts and nests.
HOW TO BREAK IT
1
3 to 7
PEARLY WHITE
ELLIPTICAL EGGS
Hatch in 2 days
in summer
2
NYMPH
feeds on blood
become adult in 3 to 6 days
3
Unfed Adult
(light gray)
feeds on blood
feeds on blood
KILL THE
MITE
Paint roosts with
CARBOLINUM
OR HEAVY OIL
4
Unfed Adult (red)
Feeds, then lays
eggs then feeds again.
Lays eggs and breeds in
roosts and nests.

Fig. 175.— Painting the roosts and filling the cracks and crevices about the droppings boards and nests control nites, if done properly and at the right time. (*Modified from the original by U. S. Dept. Agr.*)

The air-sac mite (*Cytodites nudus*) is discovered by an examination of the abdominal air sacs where the mites are seen as small grayish or light yellow specks. They are usually seen only in old birds kept under filthy surroundings and especially on premises which have been used many years for poultry. The damage done by this parasite is questionable. There is no successful treatment.

The depluming mite (*Cnemidocoptes laevis*) is not so common as most poultrymen believe. Treatment is similar to that used for scaly leg.

The connective tissue mite (*Laminosioptes cysticola*) is found in the connective tissue beneath the skin and between the muscles. The mite cannot be seen without a microscope but its presence is known by the occurrence of whitish or grayish nodules the size of a pin's head. The nodules result from a deposit of calcium salts around the bodies of dead mites. These mites are found in birds kept under such conditions as described for air sac mites. The damage caused by them is questionable and there is no successful treatment.

Of the greatest importance is a recent invader of this country, the so-called "Feather Mite" (*Liponyssus silviarum*). This mite swarms on the birds and may be found on them at any time. For this reason treatment should be applied to the bird. Finely divided sulfur as a dust, may be used in cold weather. Dipping, however, is more advisable but this can be done only in summer. An ounce of soap is dissolved in warm water and to this is added two ounces of sulphur. The mixture is frequently stirred to keep the sulphur in suspension. One bird treated in this laboratory with a nicotine sulfate solution containing 40 per cent nicotine was completely freed of mites in less than an hour. A 10 per cent solution of the agent was sprayed in the feathers of the under side of the body. Therefore, spraying a dilution of the agent in the feathers seems to suffice but great care should be taken to afford sufficient ventilation for the birds.

Scaly Leg.—The eruption of the scales on the shanks of chickens is caused by an itch mite, which burrows under the scales where it produces a spongy substance, causing the scales to become loosened. Remove infested birds from the rest of the flock.

In mild cases thorough treatment is quite successful. The shanks should be dried thoroughly and should then be treated with an ointment containing 2 per cent carbolic acid or a mixture of 1 part oil of caraway with 5 parts of vaseline.

DISINFECTANTS AND THEIR USE

One of the best disinfectants for use on a poultry plant is the compound solution of cresol. It contains 50 per cent of cresol, and ½ pt. of the compound added to 8 qt. of soft water makes an efficient disinfectant. The compound may be purchased ready for use.

Another efficient disinfectant is a 5 per cent solution of carbolic acid, which is made by adding 1 pt. of carbolic acid to 10 qt. of water.

In order to give the disinfectant an opportunity to destroy all of the germs of disease, the houses and equipment should be thoroughly cleaned before being disinfected. The walls, ceiling and floor should be gone over twice and all cracks should be cleaned out. It is particularly important to scrape and brush the floor of the house several times and it is better still if water under high pressure be used for the final cleaning.

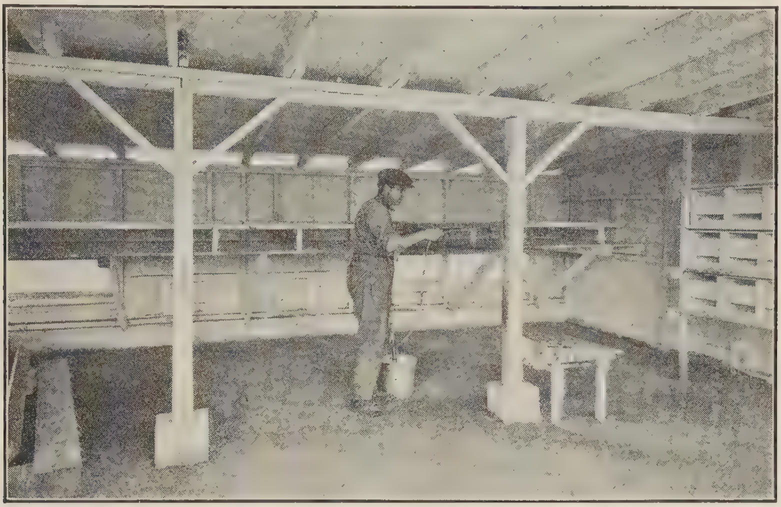

FIG. 176.—The proper cleaning and disinfection of the poultry house means that the floor, walls and ceiling be cleaned most thoroughly and then disinfected thoroughly. (*Photograph by U. S. Dept. Agr.*)

RATS AND THEIR CONTROL

Rats frequently cause considerable losses on poultry plants and farms by consuming grain and other feeds and they are often a great nuisance because of the grain sacks they destroy and the holes they dig under buildings and through walls.

One of the most effective methods of keeping various places free from rats is to poison them with red-squill powder. Squill is a perennial plant growing wild on the coast of southern Italy and in other places along the Mediterranean Sea. There are two commercial varieties of squill, white squill and red squill, the latter being the only one that is effective as a rat poison.

Munch, Silver and Horn (1929) give the following directions for preparing red squill as a rat posion.

> Powders prepared by directly drying unfermented, sliced red squill bulbs in an oven at 80° C. are usually more toxic than those prepared under other conditions. The lethal dose of squill powders prepared by this method is usually about 250 mg. per kilo of body weight for white rats; wild (brown) rats are killed by somewhat smaller doses.

Cats, dogs, chickens, and pigeons were not seriously harmed by squill powder. Food poisoned with squill either was not eaten or, if eaten, was promptly vomited. Consequently it has been indicated that red squill is non-toxic to these animals under normal conditions and when exposed in the concentration recommended for rat poisons.

Because of variations in toxicity, squill powders should be tested before being marketed and adjusted so that 10 g. of 10 per cent squill bait will kill a minimum of 1 kg. of rat. (One ounce will kill seven pounds of rats.)

Since rats vary in size from about 8 to 14 oz. each when adult, the authors found that from 2.5 to 4 g. (1/2 to 1/7 oz.) are necessary to kill adult rats.

CHAPTER XXVII

JUDGING CHICKS, EGGS AND DRESSED CHICKENS

The judging of poultry and poultry products serves two very important purposes. First, attention is drawn to the many important details affecting the quality of the stock or its product, for, without judging, the significance of the details is often overlooked. Second, judging gives rise to the comparison of one kind or class of stock or product with another kind or class, with the result that there is a keener appreciation of variations that determine the relative superiority or inferiority of an individual or group of individuals or commodities like chicks, eggs and dressed chickens.

The judging of chickens on the basis of standard and production qualities is discussed in Chap. VII, where the principle involved is the relative merits of individual birds as breeders. In this chapter the discussion on judging deals with products which are the result of breeding operations. It is very important to determine the relative quality of chicks, eggs and dressed chickens as influenced by the quality of the birds used as breeders.

Judging Chicks.—The judging of chicks is practiced quite extensively in all parts of the country, there being not only classes provided for chicks at many of the leading poultry shows but baby chick shows are frequently held in the spring of the year.

Vigor, Condition and Color.—In the judging of chicks, their vigor, condition and color are the most important factors to be considered as well as their freedom from the more important standard disqualifications, which are discussed in Chap. VII. An exhibit of one dozen or more chicks should be uniform in color and size. The 1930 edition of the American Standard of Perfection contains descriptions of the standard color of many varieties of chicks and these descriptions should be consulted when judging is undertaken. The "Standard" should also be consulted with respect to the number of points to cut for various defects which each chick or the entry as a whole may possess.

Disqualifications.—The disqualifications which prevent an entry from winning a prize include side sprigs on single combs, type of comb foreign to the breed or variety, feathers, stubs or similar growths on the shanks and toes of breeds having non-feathered shanks, web feet and an abnormal number of toes. A score card for judging chicks is given in Fig. 177.

	Points	Cuts	Remarks
Vigor	20		
Condition	20		
Color of down	15		
Uniformity of color of down	10		
Color of shanks and feet	10		
Uniformity of color of shanks and feet	5		
Size (for the breed or variety)	10		
Uniformity of size	10		
Total	100		

FIG. 177.—Score card for judging chicks.

Judging Eggs.—Eggs may be judged from the standpoint of their suitability for reproduction or for market purposes but the principles involved in judging them for either purpose are the same because the desirable qualities are identical.

Interior and Exterior Qualities.—The most important factors to be kept in mind in determining the relative quality between exhibits of eggs are the interior quality (as determined by candling), size, and uniformity of shape and shell color. Cleanliness of shell is very important, especially in the marketing of eggs, but since most exhibits of eggs are relatively clean, though some eggs may be stained, the number of points allowed for cleanliness of shell in eggs on exhibit is not as great as might be justified in scoring eggs in commerce. The texture of the shell is a factor of importance in determining the relative merits of eggs because shell texture is apparently associated with the rate of the evaporation of moisture from the egg.

The condition of the white and the yolk in an egg of superior quality are described on page 454, candling being necessary to determine the interior quality of eggs. Exhibits of one dozen or more eggs should be uniform in size, shape, shell color and shell texture.

Size Important.—The size of eggs is very important, especially when used for reproductive purposes. The recognized standard weight is 2 oz. per egg or 1½ lb. per dozen. At the same time, classes are often provided for eggs weighing not less than 22 and under 24 oz. per dozen as well as those weighing not less than 26 and under 28 oz. per dozen. Although eggs of good size are desirable, too much emphasis should not be attached to extra large eggs because they are subject to excessive breakage in transit.

Disqualifications.—Factors that should disqualify an entry include eggs with dirty shells, a broken or cracked egg, an egg with a blood clot, blood ring or partially developed embryo, a bloody egg, a moldy or musty egg or one otherwise unfit for human consumption. A score card for judging eggs is given in Fig. 178.

	Points	Cuts	Remarks
Interior factors:			
Size of air space	10		
Condition of white	15		
Condition of yolk	15		
Exterior factors:			
Size	5		
Uniformity of size	10		
Color	5		
Uniformity of color	10		
Shape	5		
Uniformity of shape	10		
Shell texture	5		
Uniformity of shell texture	5		
Shell cleanliness	5		
Total	100		

FIG. 178.—Score card for judging eggs.

Cutting for Defects.—Cutting for defects should be determined to a considerable extent by the relative value per egg for each factor, except that in the case of very serious defects the proportion to cut each egg may be in excess of the average for the particular factor involved. For instance, the factor condition of white is credited with 15 points, making each egg worth 1¼ points, and an egg slightly deficient in the quality of its white might be cut ½ point or, if it were very deficient, showing a distinctly watery white, a cut of 5 points might be made.

Judging Dressed Chickens.—The judging of dressed chickens, including broilers, fryers, roasters, capons and fowl, is important because it leads to a better appreciation of the various factors that affect quality in market poultry. Competitions in dressed chickens tends to increase efforts to produce birds of superior quality which in turn tends to increase the consumption of poultry meat.

Fundamentals.—The most important factors that affect the value of dressed chickens include the general appearance of the carcass as affected by the method of killing and dressing, the plumpness of the carcass and the age of the bird, at least in so far as immature and mature birds are concerned. Dressed poultry competitions, however, are arranged so that the various classes, such as broilers and fowls, compete among themselves and, then, each class is sometimes divided into entries of limited weights. Sometimes competitions provide for birds to be shown individually or in pairs as well as in boxes of twelve. Figure 179 gives a score card for judging dressed chickens individually or in pairs and Fig. 180 gives a score card for judging dressed chickens in boxes of twelve each.

	Points	Cuts	Remarks
General appearance:			
Freedom from blemishes	10		
Freedom from deformities	5		
Method of bleeding	5		
Freedom from feathers and down	5		
Size	5		
Cleanliness	10		
Condition and Quality:			
Plumpness	30		
Finish	10		
Skin texture	10		
Well bled	5		
Color	5		
Total	100		

FIG. 179.—Score card for judging individual dressed chickens.

	Points	Cuts	Remarks
General appearance:			
Freedon from blemishes	10		
Freedom from deformities	5		
Uniformity	10		
Package appearance	10		
Condition and Quality:			
Plumpness	30		
Finish	10		
Skin texture	10		
Uniformity of size and color	10		
Color	5		
Total	100		

FIG. 180.—Score card for judging box-packed chickens.

Cutting for defects in the various sections should be determined by the total number of points for each section and by the seriousness of each defect.

CHAPTER XXVIII

MARKETING EGGS

Although it is true that the great majority of producers do not come into direct contact with the methods employed in the marketing of the country's bulk of the annual egg crop, nevertheless, producers should appreciate the fact that marketing methods and marketing costs have a direct bearing upon production returns. As a matter of fact, the problems of production and marketing are inseparable.

This book, however, is intended primarily as a book for producers and, therefore, a detailed discussion of all of the problems in marketing eggs, including transportation and storage is not given, but only a discussion of those problems of particular interest to producers. Those interested in studying market problems in detail should consult Benjamin (1923), Slocum (1924). The 1924 U. S. Dept. Agr. "Yearbook," Separate No. 917, Steelman (1925), Card (1928*a*) and Williams (1928). Benjamin's book contains a comprehensive discussion of the entire egg-marketing problem. Enough discussion is given in this book to enable the producer to appreciate the effect of some of the major marketing problems on production returns. Two of the most important factors affecting returns to producers are the factor of quality in eggs and the function of cold storage.

Importance of Quality.—It is most important for producers to appreciate the importance of quality in eggs, whether that quality is affected by conditions of production or by conditions of marketing. The quality of eggs affects their consumption. Keevil (1927) expresses the idea in a very effective way when he says: "The incontrovertible fact, based on experience, is that stale eggs kill the demand more than high prices." Graham (1927) states the same thing in an effective way when he says: "The increased consumption of eggs will likely be governed by absolute assurance of the quality in eggs in relation to appearance and flavour and their value in regard to human nutrition."

Jones (1929) discusses the importance of quality of eggs and chickens in the following terms:

> While means may later be found to reduce the cost of producing eggs and chickens, for the present further increase in demand must arise mainly through the appeal of better quality. Hardly any food product is so dependent for demand upon its quality; one bad egg destroys the sale of several, while one exactly right calls for another and another. The best grades of eggs and chickens

are now so attractive in appearance and quality that further advance seems difficult, but advances no doubt will be made. At least, a larger proportion of the product might be produced and marketed under conditions that would put it into the higher grades.

Function of Cold Storage.—Producers in all parts of the country should appreciate the function which the cold storage of eggs serves in regulating prices in such a way as to increase production returns. That over one-half of the total annual egg crop in the United States is produced in the four months of March, April, May and June is pointed out by Heitz (1929). This uneven seasonal production, as illustrated in Fig. 181, results in a surplus of eggs during the spring and early summer seasons and a corresponding scarcity during the fall and winter months. On the other hand, the consumption of eggs is fairly stable throughout the year except that in the spring months consumption is greater than at other times but is still not enough to take up the surplus produced during that time. The surplus eggs are packed in new 30-doz. egg cases, with new fillers and flats, placed in cold storage and then taken out of cold storage to make up the shortage in egg supply during the fall and winter months.

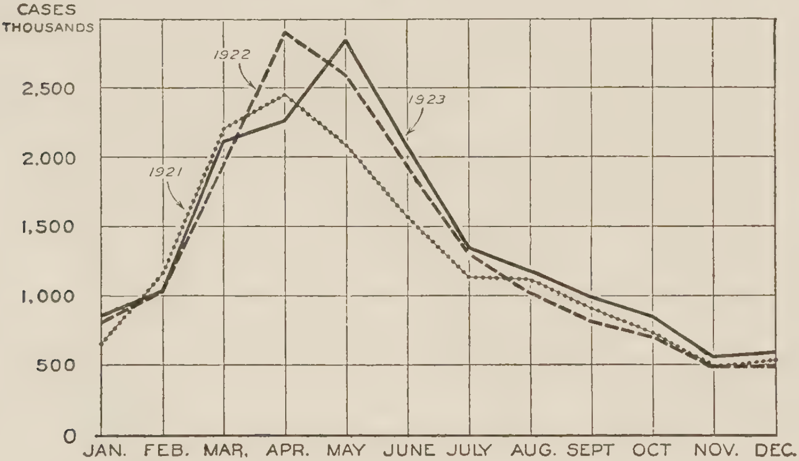

FIG. 181.—The seasonal variation in receipts of eggs on the five markets reflects the seasonal variation in production. They are heaviest during the spring months, gradually decline during the summer and fall, and reach their lowest point in November or December. From this point they increase again rapidly until they reach their highest point in April or May. (*U. S. Dept. Agr. Yearbook Separate* 917, 1924.)

The placing of eggs in cold storage and holding them there to put on the markets when there is a shortage tends to stabilize prices. This is illustrated in Fig. 182 and is explained by Slocum (1924) as follows:

> The holding of eggs in cold storage is a legitimate and needed market function which benefits both producers and consumers. Without cold storage eggs would

hardly be worth enough in many localities in the spring to pay to gather them and in the fall the supply would be far from sufficient to meet the demand, and the price so high as to be prohibitive. Through the storage of eggs there is a demand in the spring for the surplus, resulting in attractive prices to the producers and in the fall and winter a large supply of wholesome storage eggs is made available at prices within the reach of consumers. At the same time, the demand for new-laid eggs is sufficient to maintain a price on them at a level which makes winter egg production profitable.

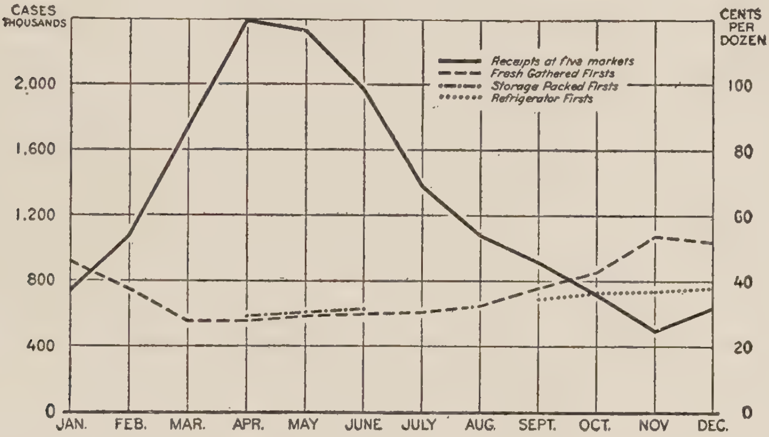

Fig. 182.—Wholesale price of eggs at New York and receipts at five markets, average, January, 1924 to December, 1926. The price of eggs rises as receipts decrease and falls as receipts increase. Storage-packed eggs bring a slightly higher price because of the better packing. The price of refrigerator eggs rises with the price of fresh eggs, but to a lesser extent. (*U. S. Dept. Agr.*)

Hydrogen-ion Concentration.—A fact of considerable importance in the storing of eggs to retain their original quality and prevent deterioration has recently been brought to light through the investigations on the hydrogen-ion concentration, expressed as pH, of fresh and stored eggs. Healy and Peter (1925) and Sharp and Powell (1927) found that the pH of the white or albumen of a fresh egg is about 7.6, whereas Buckner and Martin (1929*b*) found it to be 8.2. All of these investigators, however, found that the pH increases up to a certain point the longer the egg is kept. This means that the white increases in alkalinity. The yolk also increases in pH the longer the egg is kept. Sharp (1929) points out that the increase in the pH of the yolk is due to a loss of carbon dioxide from the yolk to the white, which in turn loses it to the surrounding air. The final result is the development of watery whites. An increase in the alkalinity of the white and yolk can be prevented by keeping the eggs in an atmosphere containing approximately 10 to 12 per cent carbon dioxide, at room temperature, or about 3 per cent, at freezing point. It seems probable, therefore, that if the introduction of carbon dioxide into cold storage rooms is practical, the quality of storage eggs will be greatly improved.

Furthermore, it is possible that 30-doz. egg cases and other containers may be lined with specially prepared paper and sealed so that eggs may be shipped direct from producer to consumer in an atmosphere containing the required amount of carbon dioxide to retain much of the original quality of fresh eggs.

The Problem of Transportation.—There are sections of the United States where eggs are produced in excess of local requirements at all times of the year. The Middle West contains about 50 per cent of the total human population and about 75 per cent of the total poultry population. Thus there is a great surplus of eggs produced in those sections of the country where feed is the cheapest. At the same time, there are highly specialized commercial poultry sections on the Atlantic and Pacific coasts that produce surpluses beyond their local requirements, the surpluses being shipped to the larger consuming markets.

The relative importance of the different states of the country from the standpoint of poultry population and eggs produced annually is shown on pages 21 and 23. The most important egg consuming centers are located in the highly industrialized sections of the country. The smaller cities throughout all parts of the country secure most of the annual requirements in eggs from the surrounding districts but the larger cities must rely upon the more important producing areas for their supply of eggs. Slocum (1924) points out that "apparently 40 to 50 per cent of the total annual holdings for the United States is stored in the five markets, New York, Chicago, Philadelphia, Boston and San Francisco." The largest problem in the transportation of eggs, therefore, is one of transporting the surpluses from the various producing areas to the largest consuming centers.

Marketing Methods.—The methods of marketing eggs from the producer to the consumer are many and varied, depending largely upon the number of channels eggs are obliged to pass through before reaching the consumer. The method of marketing employed affects the quality of the eggs as they reach the consumer and the price paid the producer. The more direct the method of marketing the less the eggs have to be handled, the less the delay, and usually the less the cost of marketing. Figure 183 shows graphically the numerous channels through which eggs are marketed.

Direct to Consumer.—Many producers market their eggs direct to the consumer or to a hotel, restaurant or retailer, this method being followed quite extensively on the part of commercial poultrymen in the vicinity of good markets. Eggs are sometimes delivered by truck or shipped by parcel post, express or freight. The two important questions that determine whether eggs can be sold by the direct method are the ability of the producer to provide a regular supply of high quality eggs from week to week and the costs of delivering or shipping. For costs of shipping eggs from one part of the country to another see page 550.

To Country Storekeeper.—Many producers sell their eggs to the country storekeeper or exchange the eggs for goods. This method, however, is gradually being replaced by other more satisfactory methods. The country storekeeper is often not in a position to hold his eggs under such conditions as to preserve the superior quality desirable in market eggs. Moreover, most storekeepers do not differentiate between good and poor quality in eggs but pay producers the same price for all eggs received and thus offer the producer no incentive to produce high quality eggs.

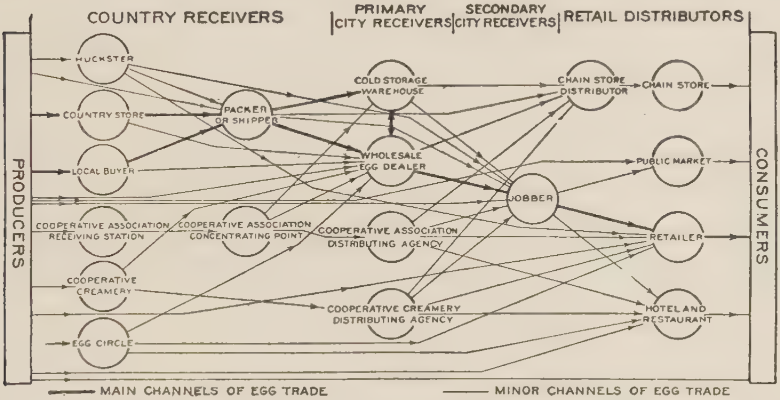
COUNTRY RECEIVERS
PRIMARY CITY RECEIVERS
SECONDARY CITY RECEIVERS
RETAIL DISTRIBUTORS
PRODUCERS
HUCKSTER
COUNTRY STORE
LOCAL BUYER
COOPERATIVE ASSOCIATION RECEIVING STATION
COOPERATIVE CREAMERY
EGG CIRCLE
PACKER OR SHIPPER
COOPERATIVE ASSOCIATION CONCENTRATING POINT
COLD STORAGE WAREHOUSE
WHOLESALE EGG DEALER
COOPERATIVE ASSOCIATION DISTRIBUTING AGENCY
COOPERATIVE CREAMERY DISTRIBUTING AGENCY
JOBBER
CHAIN STORE DISTRIBUTOR
CHAIN STORE
PUBLIC MARKET
RETAILER
HOTEL AND RESTAURANT
CONSUMERS
MAIN CHANNELS OF EGG TRADE
MINOR CHANNELS OF EGG TRADE

FIG. 183.—Eggs reach their final market through numerous channels. (*U. S. Dept. Agr.*)

Hucksters.—In some sections of the country hucksters gather eggs from farm to farm, a method of marketing having an advantage in being a regular method as compared with producers taking their eggs to the country store any time they wish. Selling eggs to hucksters, however, has the disadvantage that no premium is paid for quality eggs. Moreover, conditions under which many hucksters transport eggs about the country tend to hasten their deterioration.

Local Buyers.—There are local egg buyers located in small towns in practically all parts of the country whose business it is to buy eggs from local sources of supply, collect them in their receiving plants and pack the eggs for shipment. Since the average shipper does a relatively large volume of business, he is able to buy eggs on a graded basis and thus provide an incentive to the producer to produce good quality eggs. Unfortunately, however, many local egg buyers do not buy eggs on a graded basis.

Packing Plants.—Throughout the Middle West are located large egg and poultry packers who buy eggs from producers, storekeepers, hucksters and local buyers. The egg and poultry packing plant thus constitutes the principal concentration agency of a large egg-producing area. The eggs are packed and are then usually shipped in car lots to the principal receiving markets. Because the egg and poultry packer buys eggs in such large quantities, he is able to buy on a graded basis, though very often this is not done. Buying eggs from the producer on a graded basis stimulates the production of a higher grade of eggs than is otherwise the case.

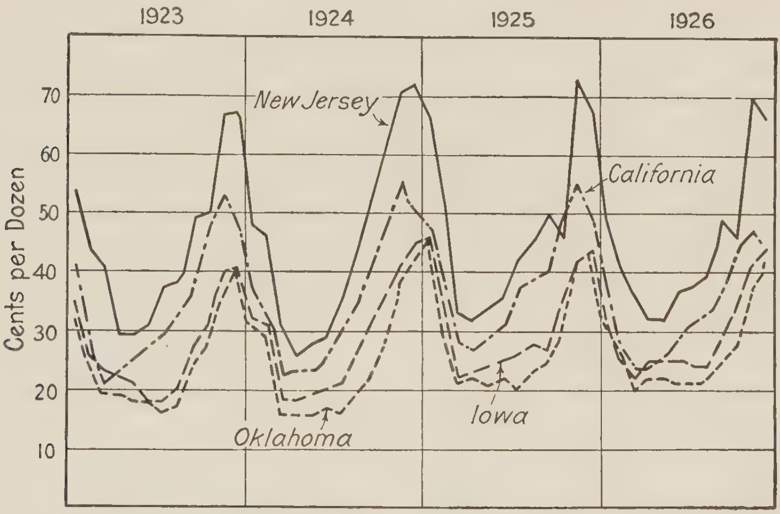

FIG. 184.—Prices paid to producers for eggs at the farm. (*U. S. Egg and Poultry Magazine.*)

Jobber or Wholesaler.—Certain producers ship their eggs direct to the jobber or wholesaler located at the terminal markets in the larger cities. Wholesale receivers consist of commission merchants and wholesale dealers, the commission merchant operating on a commission basis whereas the wholesale dealer buys the eggs and then sells them, taking a chance on a margin of profit. The producer who sells direct to the jobber or wholesale receiver is saved the trouble of establishing and maintaining contacts with the consuming trade but this method of marketing sometimes returns less to the producer than other methods.

Cooperative Marketing.—The cooperative method of marketing eggs has assumed extensive proportions in certain sections of the United States, especially on the Pacific coast. Some of the underlying features of cooperative marketing are discussed by Slocum (1924) in the U. S. Department of Agriculture "Yearbook," as follows:

> Coincident with the widespread interest in cooperative marketing of other farm products in the last few years, there has developed a marked activity in

the cooperative marketing of poultry and eggs, particularly the latter. Associations of producers have been formed in many sections of the United States for the purpose of concentrating, grading, and marketing the eggs of their members. The underlying reason for effort of this kind is dissatisfaction on the part of producers with the existing marketing agencies, either because prices are considered unsatisfactory or because no adequate recognition is given to good quality and superior market value. On the Pacific Coast, production greater than the market requirements of that section, coupled with a distance from eastern markets too great to allow individual shipments by express, has been a factor of great importance in bringing about cooperative shipments in car lots by refrigerated freight in order to provide an outlet for the surplus production.

The earliest efforts at cooperative marketing of eggs were the formation of local egg circles. A number of producers in a locality band together in such a circle either informally or under specific contract, pool their eggs, and locate a suitable market to which the eggs are shipped. A member of the circle acts as the collecting, grading, and packing agent and receives and disburses to the members the payments for eggs. The member so acting either performs this service gratuitously or receives a specified sum for each dozen eggs handled. Many of these circles require the members to stamp each egg or carton of eggs marketed with the number or name of the circle and with a number representing the individual member. In this way responsibility for any eggs furnished which are not of proper quality and which might therefore be the cause of complaint can be traced to the member furnishing the eggs and steps taken to prevent a recurrence. Many of these egg circles have succeeded in securing prices which are materially better than the local prices otherwise obtainable by members. (Although egg circles have performed a useful service, the trend is now toward larger cooperative units.)

Another form of cooperative effort in egg marketing is the utilization of the cooperative creamery as the collection and marketing agency. Eggs are collected from the creamery patrons along the established cream routes or are delivered to the creamery when milk or cream is brought in. Because the milk or cream must be delivered at frequent and regular intervals and delivery of the eggs can be made at the same time without extra effort, the creamery is in a good position to receive the eggs while they are fresh and of excellent quality. The creamery is also often in a position to provide the necessary collection, grading, and holding facilities at a small overhead cost, and, since eggs and butter are usually closely associated throughout the process of market distribution, is also often in a position to provide good outlets with a minimum of effort.

Cooperative marketing through the egg circle or through the creamery is usually local in character. Cooperative effort on a scale covering a larger producing territory is undertaken through the organization of the egg producers into an association formed specifically for that purpose. Some of these associations have failed, but others have succeeded, and the movement continues to grow rapidly and the chances of success improve as conditions desirable for the formation of such associations are better understood and as the form of organization and method of operation become more nearly perfected.

The chances for success for a cooperative egg-marketing association depend upon a number of conditions. Chief among these may be mentioned the following: A plainly evident need for cooperative marketing; a sufficient number of cooperators and a sufficient volume of eggs to carry the necessary overhead without its being burdensome and to enable advantageous marketing contracts or outlets to be arranged; production sufficiently concentrated to allow economical handling; the cooperative spirit on the part of the producers; a sufficient spread between local prices and the prices available in the terminal markets to make the effort worth while; suitable market outlets; a definite and practical plan of marketing; capable management and a suitable form of organization. The attempt should not be made to organize such an association until a thorough survey has been made of the situation and a definite plan of action outlined and agreed upon.

One of the most important features of successful cooperative egg-marketing associations is the marketing contract. By the terms of this the association agrees to market to the best possible advantage all eggs delivered to it. The producer agrees to deliver all his eggs, except such as he uses at home or for hatching purposes, to the association for a term of years. He may be given the right by the association to market his eggs or a part of them elsewhere, but must then pay to the association the same amount per dozen as is deducted by the association when making the sale for the member. Contracts of this character have been declared by the courts to be legal and binding upon the association and the individual members. Such a contract with each member is very necessary in order that the association may hold its members and may know within reasonable limits the volume of eggs at its disposal throughout the year with which to make sales contracts and fill orders.

The eggs received at the grading station of the association are graded, the shipper being given credit on the books of the association for the number of dozens of eggs of each grade delivered. The eggs of the same grade from the different producers are then packed together and forwarded to market, where they are disposed of through the regular channels which the association has established. All eggs of like quality received during a certain length of time, usually a week, are pooled together, and payment is made on the basis of the average price received for each grade in the pool minus the regular deduction for operation. A conservative partial payment or advance may be made on receipt of the eggs at the grading station, the balance realized being returned as a deferred payment upon final settlement of each pool. At the end of the year if a surplus has accumulated as a result of the regular deductions which is in excess of the amount needed for use in the association's business, this excess is returned to the members in proportion to the quantity of eggs marketed for each by the association.

The services performed by a cooperative egg-marketing association for its members are identical, so far as they go, with the services performed by the private agency or succession of such agencies concerned with the movement of eggs through the ordinary channels of trade from the producer to the consumer. To be successful, therefore, it is essential that the association perform these services just as efficiently or more efficiently than these private agencies. Ordinarily the association confines its activities to concentrating, grading, packing, and shipping the eggs to the final market, utilizing the already existing distribution agencies after the eggs reach that point. In some cases, however, associations maintain salesrooms in one or more of the terminal markets and assume the functions of the wholesale dealer and to some extent that of the jobber. Not much has been done as yet in the way of assuming the functions of the retailers, but this is a possible development of the future. Associations sometimes process and place in cold storage or place in storage without processing a part of the surplus production of the spring season. This is done either to strengthen their market position under unusually heavy receipts or to help in supplying their regular outlets during the period of scarcity in the fall and winter. Sometimes the holding of eggs in cold storage is undertaken by an association as a speculation. This is generally inadvisable and may cause a serious setback in the affairs of the association, especially during its early existence.

The most common causes of failure of cooperative egg-marketing associations have been unfavorable conditions of production, inefficient management, lack of a definite and practical plan of marketing, lack of the cooperative spirit on the part of the members, and competition on the part of dealers which the association is unable to meet successfully.

Shipping Containers.—Eggs are marketed for the most part in cartons, parcel-post packages and egg cases. These containers should be well made to avoid breakage in shipping and at the same time light enough to avoid excessive shipping charges.

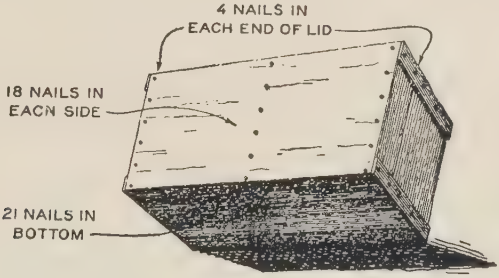

Fig. 185.—A properly constructed egg case must be well nailed. (*U. S. Dept. Agr.*)

Cartons.—Cartons are pasteboard containers holding ½ or 1 doz. eggs, in the latter case being made in two styles, one holding 3 rows of 4 eggs each and the other holding 2 rows of 6 eggs each. Cartons are used in selling eggs direct from the producer to the consumer and by the retail trade. Since the carton of 2 rows of 6 eggs each fits into the 30-doz. egg case, it is used much more frequently than the other style.

Parcel-post Containers.—Parcel-post packages are made in various styles and sizes to hold from 1 doz. to several dozen eggs. Further information on parcel-post packages and the proper way to pack eggs in them for shipment through the mail is given by Flohr (1928) who says that "More parcels of eggs than of any other one product pass through the mails."

Standard Cases.—Egg cases are for the most part of the 30-doz. capacity, with a partition in the center of each case, so that each half of the case holds 15 doz. The cases must conform to the requirements of the Express and Consolidated Freight Classification. Eggs are packed in the cases in flats, cup flats and other cushion flats and fillers, which should be of good weight, hard calendered in finish and perfectly dry. Excelsior pads in the tops and bottoms of the cases help to avoid breakage. Sometimes a third excelsior pad is used beneath the top layer of eggs. Egg cases should be nailed firmly before being shipped.

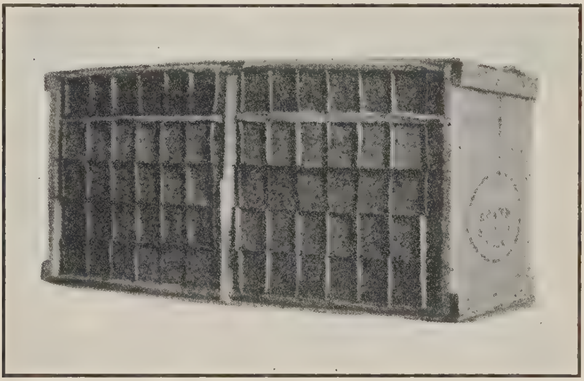

Fig. 186.—A 30-dozen egg case with standard fillers and flats, and with three excelsior pads to a side is a very satisfactory method of packing eggs. If pads are used, flats are omitted. (*U. S. Dept. Agr.*)

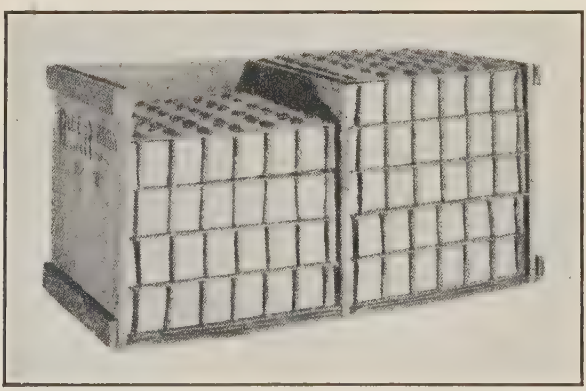

Fig. 187.—An egg case packed with white spruce fillers and cup flats makes an attractive package, protects the eggs well from breakage, and is a good package for cold storage because of the odorless character of the packing materials. (*U. S. Dept. Agr.*)

Factors Affecting Quality in Eggs.—The term "quality" when applied to market eggs means that condition of shell and contents of eggs which can be marketed in such a manner as to give the greatest satisfaction to the consumer.

The formation and structure of the egg have been discussed on pages 67 and 69 and the chemical composition of the egg has been discussed on pages 2 and 321. This section of the book deals primarily with the physical structure of eggs and with certain chemical and bacteriological developments that take place in eggs as the result of marketing and storage conditions.

The shell of a market egg should be smooth on the surface, thick enough to give sufficient strength to withstand marketing conditions and rather dull in appearance. Eggs marketed together should be uniform in size and color. The shells should always be clean. Glossy shells indicate that the eggs have been handled considerably, held for some time or incubated for some length of time. Stained shells indicate that the eggs have been in contact with moisture.

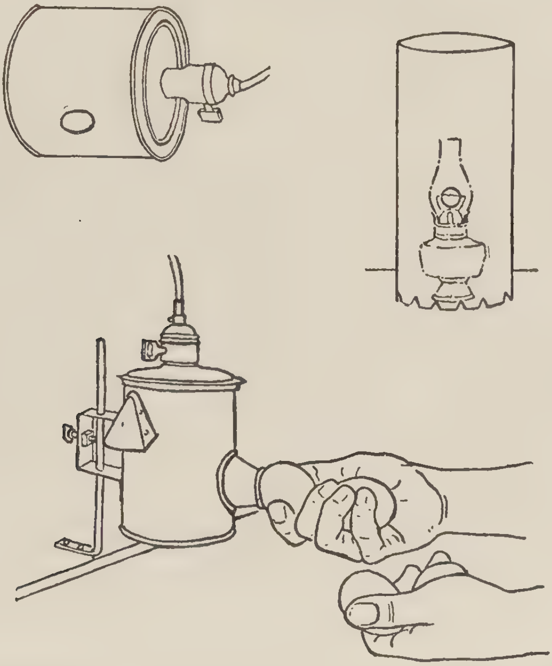

Fig. 188.—Upper right: a length of stovepipe and a lamp are easily converted into an egg candling device.

Fig. 189.—Upper left: An electric light and a tin can with a removable top make a satisfactory egg candling device.

Fig. 190.—Lower: showing the proper way to hold eggs while candling them. (*U. S. Dept. Agr.*)

Candling to Determine Quality.—In order to determine the quality of the interior of the egg it is candled or tested before a light, usually in a dark or partially darkened room. The contents of the egg are observed by placing the egg between the bright light and the eye of the observer with the egg about one foot below and one foot in front of the eye. The large end of the egg is held up and the egg is given a quick twirl, the quicker the better, in order to cause the white or albumen and the yolk to rotate. The rotation of the egg enables the observer to see the yolk more readily and to determine the condition of both white and yolk. Further details in candling eggs are given by Pennington, Jenkins and Betts (1918) and by Slocum (1928).

All producers should know enough about the condition of the interior of fresh eggs in order to distinguish such eggs from stale ones and eggs in which the internal conditions are such as to make them undesirable for marketing. Producers should also know something of the factors that produce undesirable conditions in eggs.

Slocum (1928) describes fresh and stale eggs as they appear upon being candled:

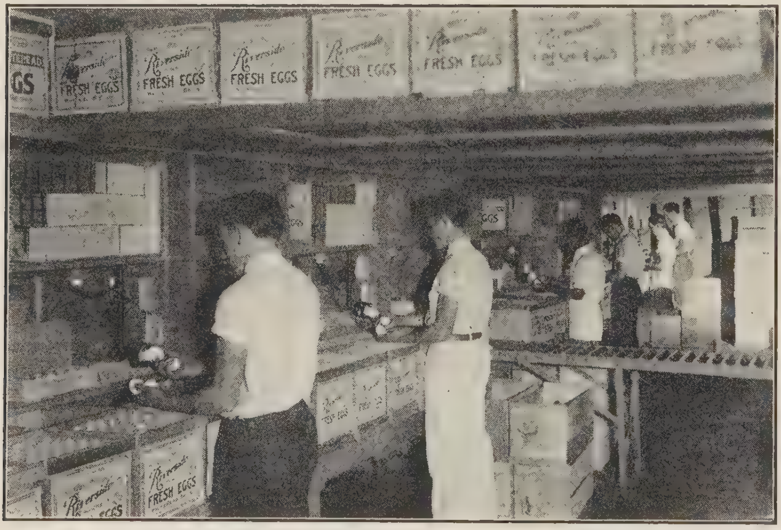

FIG. 191.—Candling or testing eggs and grading them according to quality. (*Photograph by Whitehead Bros.*)

The air cell develops at the large end of the egg by separating the two shell membranes and filling this space with air. In eggs of the best quality the air cell must be small, not over one-eighth of an inch in depth, measured from the end of the shell to the plane passing through the egg at the lower edge of the air cell where it touches the shell. The air cell should occupy a fixed position and not be movable. Large air cells are an indication of staleness or age; movable air cells indicate broken membranes and detachment of the chalazae, permitting the yolk to settle and to stick to the shell.

The yolk of a fresh egg should be only dimly visible as a shadow when the egg is turned before the candle. It should have limited freedom of motion. Rapid and freer motion and greater visibility of the yolk are associated with lower quality. When broken out in a dish the yolk of a fresh egg is well rounded or "stands up" well; the yolk of a stale egg is flatter and more spread out. The color of the yolk may vary all the way from a pale to a deep yellow. The color depends largely upon the amount of green feed which the hens have received, and therefore varies to a considerable extent with the season.

The color of the yolk may affect the price to a limited extent, especially where some special demand is to be met. Most consumers prefer a fairly deep-colored yolk, but there is a special demand in the New York City market for eggs with pale yolks.

The white of an egg of extra quality should be firm and clear. Weak or thin white indicates staleness, and bloody white, or the presence of any foreign substance, such as a blood clot or meat spot, reduces or destroys the market value.

It should be noted here that the color of the yolk of fresh eggs is affected by the character of the feed given the laying hen, certain green feeds producing a darker yellow than when they are not used, as discussed on page 372.

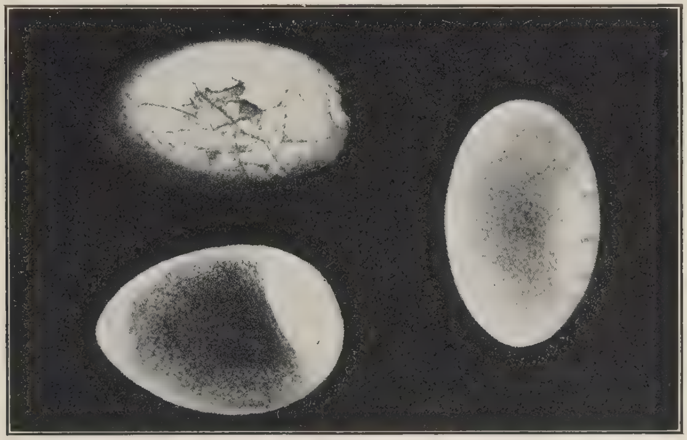

Fig. 192.—Upper left, moldy cracked egg in daylight. Lower left, black rot before the candle. Right, egg with moveable air cell before the candle. (*U. S. Dept. Agr.*)

Blood Clots.—Eggs with blood clots in them sometimes are observed among fresh eggs. The blood clot usually appears on the side of the yolk when the egg is candled. The blood clot is caused by a rupture of a blood vessel in the ovary, the blood collecting on the side of the yolk. Eggs with blood clots should not be marketed.

Bloody Eggs.—Bloody eggs are those in which the blood from a ruptured blood vessel in the ovary or oviduct mixes with the white of the egg, giving it a bloody appearance.

Meat Spots.—Eggs with meat spots in the contents are those in which a piece of the tissue of the oviduct of the hen has been included with the white while the egg was passing down the oviduct. Although eggs with meat spots are quite edible after the meat spots are removed, when the eggs are broken, it is not advisable to market them.

Body Check.—An egg that is termed a "body check" is one in which the shell has apparently been cracked in the uterus of the oviduct and then more shell material is deposited over the crack. The objection to marketing these eggs is that the shells may be easily broken and thus smear other eggs when being shipped.

Checks and Blind Checks.—Checks are eggs that are only slightly cracked without causing the contents to leak. A blind check is an egg in which the check is not easily discernible.

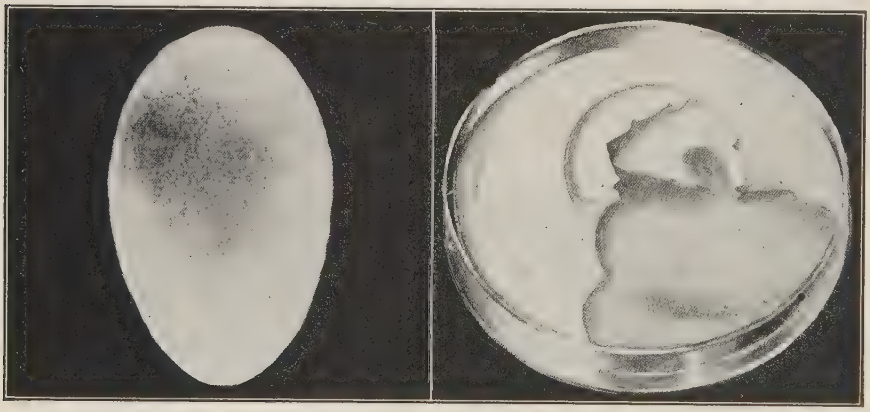

Fig. 193.—Egg with yolk slightly stuck to the shell before the candle and out of the shell (*U. S. Dept. Agr.*)

Leakers.—Leakers are cracked eggs from which the contents are leaking.

Light and Heavy Floats and Heat Spots.—The excessive heating of eggs, whether from extreme exposure to the rays of the sun or by being held in warm places, gives rise to three different kinds of eggs known as "light floats," "heavy floats" and "heat spots." Light floats as they appear before the candle have enlarged air cells and darkened yolks. The eggs have a darkened and heated appearance and deteriorate more readily than fresh eggs. Heavy floats are more seriously defective than light floats because the air cells are larger and the yolks are much darker and closer to the shell. Heat spots are eggs in which embryo development has commenced but no blood appears.

Blood Rings.—An egg with a blood ring appearing on the yolk is the result of the development of the embryo for a few days and then it dies, leaving the blood of the embryo collected in a small ring. Producers should realize that the germ of a fertile egg starts to develop at about 68° F. One way of largely avoiding the occurrence of eggs with blood rings is to keep the males away from the females except during the breeding season.

Moldy and Musty Eggs.—Moldy and musty eggs are the result of the development of molds on the outside or inside of the shell, especially if the shell is cracked. The development of molds usually takes place when there is warmth, plenty of moisture and lack of ventilation. Moldy and musty eggs have a pungent odor and impart this odor to surrounding eggs. Producers should always use clean cases, flats and fillers.

Rots.—Rots of various kinds are the result of bacterial infection. Rettger (1913), Kossowicz (1913) Pennington et al. (1914) and Hadley and Caldwell (1916) all agree that normal fresh eggs are practically sterile. Pennington et al. point out, however, that moldy eggs and those with rots contain a relatively high percentage of bacterial infection. Many kinds of eggs with rots are found in commercial practice but are not encountered ordinarily by the producer.

"Grass" Eggs.—Grass eggs are those with olive-colored yolks or those in which the whites appear slightly greenish when candled. Benjamin (1923) says that "it is generally thought that eggs acquire this defect by being left out in the grass, and probably this is a frequent cause. It is also believed that the holding of the eggs in any moist place may cause the development of the grass egg, if a certain type of bacteria gain entrance to the egg. Grass eggs are not suitable for food purposes."

Odors.—Eggs readily absorb odors and flavors of various kinds and, therefore, they should be kept away from such things as coal oil, oranges, lemons and disinfectants.

Washing Objectionable.—Washing eggs reduces their keeping qualities because the natural bloom is removed and the pores of the shell are opened.

Maintaining the Original Quality of Fresh Eggs.—Benjamin (1923) says that "much of the cost of egg distribution is determined by the quality of the product which leaves the farm. The greater the care and expense given to the eggs on the farm, the less is the expense required during the distributive processes later on." This is a point the importance of which most producers do not appreciate. They often forget that the marketing of bad eggs means loss in shipping costs and a lower price for the good ones. It should be obvious to all producers that the higher the quality of eggs marketed, the less candling required, the lower the operating expenses and the higher the prices received.

An interesting fact has recently been brought to light concerning an apparent seasonal change in the quality of eggs. Bakers have found that eggs laid in March and April produce more volume in cake than eggs laid in June and July. Apparently there is a change in the whipping quality of the two groups of eggs although the cause for the change is not known. The decrease in whipping quality occurs earlier in the southern parts of the country than in the northern parts. The only plausible explanation that can be offered at present is that those eggs produced during March and April have more "body" than those produced later.

Slocum (1924) gives some very pertinent advice regarding steps that should be taken to insure maintaining the original quality of fresh eggs.

> Practically all eggs are of equally good quality when first laid. But if they are to retain their quality and reach market in good condition they must be given proper care and handling by the producers. There is no process or step in marketing which can improve an egg of poor quality. All that can be done is to preserve the original quality. Good care on the farm is therefore a necessary prerequisite to the marketing of good eggs.
>
> First of all it is necessary to have good poultry stock of a standard variety in order to produce eggs of uniform size and color. The flock must be well-housed, fed, and cared for in order to increase their productivity. As soon as the hatching season is over all male birds should be disposed of or separated from the flock so that only infertile eggs of superior keeping quality will be produced. Nests, clean and sufficient in number, must be provided in order that the largest possible percentage of the eggs may be kept clean. Dirty eggs should never be washed unless they are to go into channels of immediate consumption. Washing reduces the keeping quality and results in losses, especially if they are to be placed in storage.
>
> Eggs must be gathered frequently, at least once a day, and preferably twice a day during very hot or very cold weather to prevent their becoming heated or frozen. They should be kept in a cool, moderately dry place to maintain their quality and to prevent mold development. All very small, very large, or very dirty eggs should be used at home or sold to local consumers and not included with those shipped to market.

In addition it might be added that only clean egg cases, fillers and flats should be used in shipping eggs.

Grading Eggs.—It has been shown previously that all eggs as they are sold by producers are not of the same quality, but even if they were they would show differences in quality before they reached the consumer. Differences in methods of handling eggs and different lengths of time for various lots of eggs to reach the various markets produce changes in the quality of eggs. In order to provide a practical basis for reporting prices and for buying and selling according to quality, the various markets have established certain grade standards based on quality.

The principles underlying the grading of eggs and definitions of the terms used for the various grades are given in detail by Benjamin (1923), but since the great majority of producers do not do their own grading, the matter is not discussed in detail here. However, producers are frequently paid for their eggs on a graded basis and consequently should have some knowledge of the terms used for the different grades in the different markets. For this purpose Table 56, from Benjamin (1923), is given.

It is apparent from Table 56 that there is lack of uniformity in the system of grading eggs in the various markets. A grade term used in one market does not necessarily signify the same quality of egg as the

TABLE 56.—COMPARISON OF EGG GRADING SYSTEMS (Benjamin, 1923)[1]

	New York	Chicago	Kansas City	San Francisco	Canada
Classification:	Fresh gathered Hennery Held fresh Storage packed Refrigerator Processed Duck and goose	Fresh gathered Storage packed Refrigerator	Fresh gathered Storage packed Refrigerator	California Eastern	Fresh Storage Preserved Cracked and dirty
Grades:	Extras Extra firsts Firsts Seconds No. 1 dirties No. 2 dirties No. 1 checks No. 1 pullets No. 2 pullets	Extras Standards Firsts Ordinary firsts No. 1 dirties No. 2 dirties	Extras Firsts Seconds Current receipts No. 1 dirties No. 2 dirties	Extras Extra firsts Firsts Seconds Thirds Extra pullets Extra first pullets Undersized pullets No. 1 dirties No. 2 dirties	Specials Extras Extra firsts Firsts Seconds Pullet extras
Best grade:	Hennery extras	Fresh gathered extras	Fresh gathered extras	Fresh California extras	Fresh specials
Description of best grade:	Packed in new or standard cases. Uniformly good size, free from dirty eggs. 90% clean, fresh, reasonably full, strong, sweet eggs. Average 46 lb., net. Dead loss, 3 eggs per case. Total average loss, 1 doz.	Packed in new white-wood cases free from small and dirty eggs; contain fresh, reasonably full, strong in body, sweet eggs in proportion from 70 to 90%, depending on season. Total average loss, ½ to 1 doz., depending on season.	Packed in new white-wood cases 90% must be free from small and checks, fresh, reasonably full, strong bodied sweet eggs. Must weigh 55 lb. gross. No loss allowed.	70% must be entirely white and 30% almost white; reasonably clean; reasonably uniform size. 85% must be No. 1 stock, quality good, sound, sweet and full. Total average loss, 1 doz. No washed eggs allowed.	Uniform size, 25-oz. to doz. or over 47 lb. net per case. Clean and free from stain, strong and sound in shell; air cell small, not over 3⁄16 in. in depth; white of egg to be firm and clear and yolk dimly visible.

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[1] BENJAMIN, EARL W., "Marketing Poultry Products." By permission of John Wiley & Sons, Inc., publishers.

TABLE 57.—U. S. STANDARDS OF QUALITY FOR INDIVIDUAL EGGS[1]
(Voorhies, 1926)

Quality factors	Specification of each quality factor						
	U. S. special	U. S. extra	U. S. standard	U. S. trade	U. S. standard dirty	U. S. trade dirty	U. S. check or crack
Shell	Clean; sound	Clean; sound	Clean; sound	Clean; sound	Stained or dirty but sound	Stained or dirty but sound	Clean or dirty; cracked but not leaking
Air cell	1/8 in. or less; localized; regular	2/8 in. or less; localized; regular	3/8 in. or less; localized; may be slightly tremulous	May be over 3/8 in.; may be bubbly or freely mobile	3/8 in. or less; localized; may be slightly tremulous	May be over 3/8 in.; may be bubbly or freely mobile	May be over 3/8 in.; may be bubbly or freely mobile
Yolk	May be dimly visible	May be visible	May be plainly visible; mobile	May be plainly visible; dark in color; freely mobile	May be plainly visible; mobile	May be plainly visible; dark in color; freely mobile	May be plainly visible; dark in color; freely mobile
White	Firm; clear	Firm; clear	Reasonably firm	May be weak and watery	Reasonably firm	May be weak and watery	May be weak and watery
Germ	No visible development	No visible development	Development may be slightly visible	Development may be clearly visible but no blood showing	Development may be slightly visible	Development may be clearly visible but no blood showing	Development may be clearly visible but no blood showing

These standards of quality for eggs were proposed by the U. S. Department of Agriculture and, at a national conference of the egg trade held in Chicago in January, 1925, were adopted as the National Standards of Egg Quality. These standards form the basis of the proposed U. S. Grades for Eggs, therefore a knowledge of them is essential to an understanding of the proposed U. S. Egg Grades.

[1] Table furnished by the Bureau of Agricultural Economics, U. S. D. A.

same grade term in another market. There is thus confusion in the buying and selling of eggs among the various markets. The need is apparent for standardization in grading systems and in the use of similar terms for the same quality of egg.

The Bureau of Agricultural Economics of the U. S. Department of Agriculture long since realized the need for the standardization of grading systems applicable to all parts of the country and in 1925 proposed standards of quality applicable to individual eggs, given in Table 57.

The information given in Table 57 should be of great value to producers. It makes clear the extent to which the different grades of eggs differ in respect to the quality found in the shell, air cell, yolk, white and germ.

Termohlen (1929*a*) discusses the importance on the part of the farmers of Iowa, an egg-surplus producing state, selling eggs on a graded basis.

> We might say that considerable emphasis is given to the reasons why eggs should be sold on a grade. In the past, the principal reason held forth has been the direct statement of increased profits. We feel such direct statement is treading on dangerous ground. Our chief appeal is that of reflecting back to the producer the demands of the consumer. It is only logical that a producer should know consumers' demands for his products. This is especially true in a surplus-producing area such as Iowa, where the bulk of the product is shipped out of the state to consumers several hundreds of miles away. The need of reflecting back the consumers' demand is brought home forcibly when we consider the following statistical information: In 1927 there were received at the four markets—New York, Chicago, Boston and Philadelphia—approximately 15,000,000 cases of eggs; 2,500,000, or 16⅔ per cent or one sixth of this total, came from Iowa. Farmers having these facts pointed out to them, more readily realize the possibility of increasing returns if the consumer is given what he wants.

The Bureau of Agricultural Economics of the U. S. Department of Agriculture has proposed tentative buying grades of eggs for use in the purchase of eggs by storekeepers, local egg buyers and others who purchase eggs from producers on a graded basis at country buying points.

Regarding the system of grading eggs on the basis of quality as proposed by the Bureau of Agricultural Economics of the U. S. Department of Agriculture, Termohlen (1929*b*) makes the following observations:

> That this system as suggested is practical is shown by the results which have been demonstrated in Canada. About 10 years ago the Canadian government started a campaign to better the egg market for producers and at the same time give the consumers a higher quality product. In 1922 a Dominion law was passed establishing standards and grades of eggs. Three groups of grades were established, very similar to the three United States grades groups. Government inspection is in force in the different provinces. The benefit of the Canadian system is shown by the fact that in 1920 the per capita consumption was 16.8 doz. eggs and in 1927 it was 29.67 doz. eggs—an increase of 76.6 per cent.

TABLE 58.—TENTATIVE U. S. BUYING GRADES FOR EGGS

U. S. buying grades	Average weight	Shell	Air cell	Yolk	White	Germ
U. S. extras	24 oz. net per doz. with minimum at the rate of 22 oz. for individual eggs	Clean; sound	Depth of $\frac{1}{4}$ in. or less; localized, regular	May be visible	Firm; clear	No visible development
U. S. standards	24 oz. net per doz. with minimum at the rate of 22 oz. for individual eggs	Practically clean; sound	Depth of $\frac{3}{8}$ in. or less; localized; may be slightly tremulous	May be plainly visible; mobile	Reasonably firm	Development may be slightly visible
U. S. trades	22 oz. net per doz. with minimum at the rate of 18 oz. for individual eggs	Clean or dirty; sound	Depth may be over $\frac{3}{8}$ in.; may be bubbly or freely mobile	May be plainly visible; freely mobile	May be weak and watery	Development may be clearly visible but no blood showing
U. S. checks and cracks	No specified or minimum weight required	Clean or dirty; checked or cracked but not leaking	Condition of air cell, yolk, white and germ same as permitted in the grade of trades			

Processed Eggs.—It has been pointed out previously that the highest quality in eggs is found in fresh eggs when they are produced under sanitary and otherwise satisfactory conditions. A method of treating fresh eggs to preserve the quality has been developed in recent years, this method being known as "processing" or "sterilizing." The eggs are dipped for a few seconds in a solution of odorless, tasteless mineral oil heated to a temperature of 225 to 240° F., although recently a much lower temperature has been used with good results. The coating of the eggs with the oil seals the pores of the cells. This prevents the evaporation of the water content from the egg and tends to preserve its original quality.

The bulk of the processed eggs are placed in cold storage and when they are removed from storage, they are sold in the processed condition or sometimes the oil is removed from the shells by passing the eggs through a sand blast. This is sometimes referred to as "manicuring" the processed eggs and when so treated they must be sold soon thereafter because the pores of the shells have been opened, allowing relatively rapid evaporation.

Dried and Frozen Eggs.—The preparation of dried and frozen eggs is of interest to producers because it has a direct bearing on the egg-price situation during the spring of the year. Many small, dirty and cracked eggs produced during the spring months are collected in egg-breaking plants.

Heitz (1929) discusses the manner of preparing dried and frozen eggs briefly as follows:

> The preparation for frozen and for dried eggs, up to a certain point, is practically the same. The eggs to be used are first carefully candled, and all the spoiled eggs that can be detected are removed. The breaking rooms are light and sanitary, and all utensils are frequently sterilized. Each egg is broken into a cup, and is thoroughly observed by sight and smell. The liquid egg is then placed in a churn to be thoroughly mixed with other liquid eggs, and then frozen in cans containing about 30 lb. of the liquid. The white and yolks may be mixed together or may be kept separate. The cans are then placed in a sharp freezer with a temperature below zero, and are frozen solid. As the freezing causes expansion of the liquid, the cans are filled only to within a few inches of the top. After the liquid is frozen, enough additional liquid is poured in to fill the cans, which are again returned to the sharp freezer and frozen solid. They may then be removed to a temperature from 0 to 5° F., at which they may be held until sold.
>
> If sufficiently cold temperature is available, or if cans can be placed directly against the refrigerator coils, the expansion of the liquid does not occur and the cans may be filled at the first pouring and the extra labor of repouring avoided.
>
> Dried eggs are usually prepared by spraying the liquid in a high-ceilinged room heated to a temperature of 160 to 170° F. The spray dries and forms a powder as it descends to the floor and is then packed in containers and is ready

for market. Whites alone do not spray so easily. They are usually prepared by drying in metal pans. The product is then scraped off and is sold as albumen.

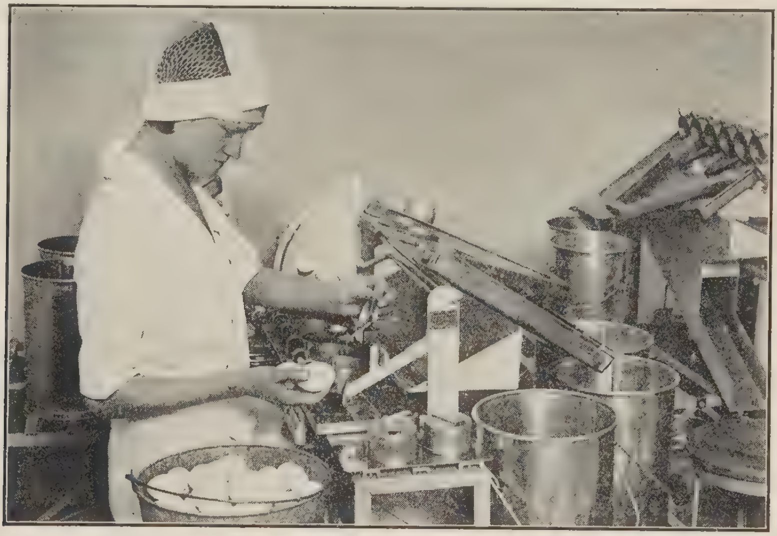


Fig. 194.—A mechanical apparatus for breaking eggs and for separating yolks and whites for the preparation of frozen and dried egg products. (*Photograph by Pacific Craftsman and Breeder.*)

Fig. 195.—The interior of an egg-breaking plant. The manufacture of frozen and dried eggs is an important industry. (*Photograph by Poultry Craftsman and Breeder.*)

Flaked eggs are prepared by pouring the mixed liquid over a roller or belt which is heated to a temperature of 140 to 150° F. As the liquid dries, it is scraped off and packed in containers and sold as flaked eggs. The dried product is usually kept in coolers but will keep for a considerable length of time in ordinary temperatures.

Home Preservation of Eggs.—The home preservation of eggs has been practiced for many years. When prices are low in the spring it is frequently advantageous to preserve a few eggs for cooking and baking purposes during the fall and winter months. Only fresh eggs of the very best possible quality should be used and they should be clean and sound in shell.

The eggs are preserved in a solution of water glass (soluble sodium silicate). To 9 parts of boiled rain water that has been cooled add 1 part of water glass. Put the solution in an open crock and place the eggs in the solutions as they are gathered every day. Place the eggs in the crock with the large end uppermost and be sure that there is at least 2 in. of the solution above the top layer of eggs. The eggs may be kept in the solution for several months. If the eggs are to be cooked, pierce the air cell with a needle to prevent the egg from cracking while being cooked.

CHAPTER XXIX

MARKETING CHICKENS

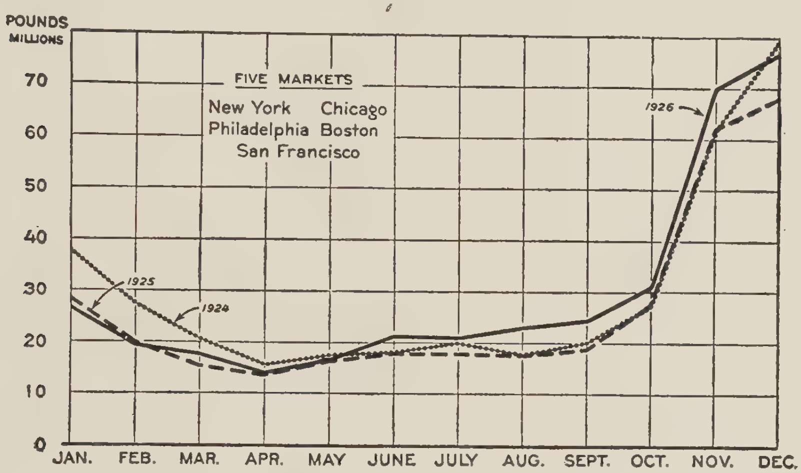
The various problems involved in the marketing of chickens are of interest to producers because most of these problems have a direct bearing upon the returns which producers receive for their chickens. As in the case of the marketing of eggs, so in the marketing of chickens, the problems of marketing cannot be separated entirely from the problems of production. The methods of rearing chickens and the rations fed affect to a considerable extent the quality of chickens marketed, which in turn determines the price received.

Importance of Quality.—There are two things which producers should appreciate that have a direct bearing upon prices paid for chickens of various classes. The first is the quality of chicken meat. The palatability of chicken meat is a deciding factor in determining its demand by consumers and the price which consumers are willing to pay. The quality of chicken meat may be affected by the breeding of the birds, by conditions of production as well as by conditions of marketing. Producers should appreciate the fact that too much chicken meat of poor quality is marketed with the result that the average price of all chicken meat is lowered and there is also a great deal of wastage.

The Function of Cold Storage.—The second thing that producers should appreciate is the service rendered by cold storage in stablizing prices. Most of the chickens raised annually are marketed in the fall and early winter. More chickens are marketed then than can be consumed and if there were no cold storage facilities for holding poultry, prices during the fall and winter months would be ruinously low. Since cold storage facilities are available, producers do not have to keep their chickens on the farms during the winter months but can market them when they are at the proper age and in the best condition to bring satisfactory prices. Cold storage renders a service to consumers by ensuring an adequate supply of chicken meat at all times of the year.

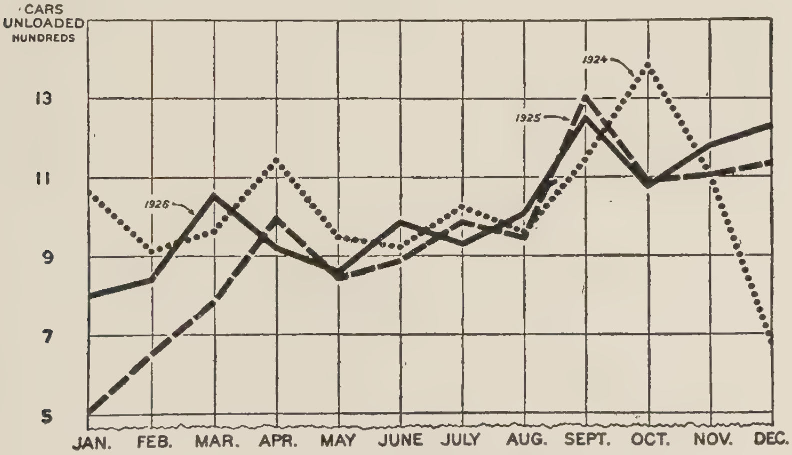
The Problem of Transportation.—In other sections of this book it has been shown that the Middle West is the most important poultry producing section of the United States. It has also been pointed out that the larger cities in the northeastern highly industralized sections constitute the most important markets for poultry products. The surplus of chickens reared in the Middle West and other surplus producing sections, such as the Pacific coast, must be transported great distances to the consuming centers.

For efficiency and economy in handling, the poultry sold in small lots from the individual farms must be assembled at central points and shipped, either alive



—RECEIPTS OF DRESSED POULTRY AT FIVE MARKETS, 1924-1926

FIG. 195a.—Receipts of dressed poultry at five markets, 1924 to 1926. Receipts are heaviest in the late fall and early winter. They decline during the late winter and early spring and remain relatively light throughout the summer. (*U. S. Dept. Agr.*)



—FREIGHT UNLOADS PLUS EXPRESS RECEIPTS OF LIVE POULTRY, NEW YORK CITY, 1924-1926

FIG. 196.—Freight unloads plus express receipts of live poultry, New York City, 1924 to 1926. The abnormally low receipts at the end of 1924 and at the beginning of 1925 were due to an embargo placed by New York City against live poultry from a considerable number of states because of disease conditions prevailing at that time. (*U. S. Dept. Agr.*)

or dressed, in large lots, often in car lots. Much of the poultry is dressed before shipment to the final markets and this requires establishments especially equipped for the purpose. The dressed poultry is highly perishable unless handled at low temperatures, and for this reason the use of refrigerator cars in shipping is essential. To prevent the heavy shrinkage in weight in shipping live poultry, it is necessary to use cars especially constructed for this purpose, which make it possible for the poultry to receive proper care and feeding in transit. The trans-

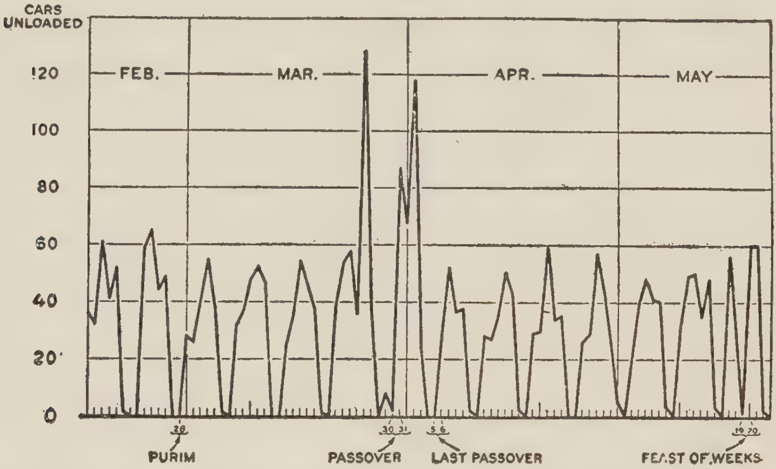


FIG. 197.—Freight unloads plus express receipts of live poultry, New York City, showing the influence of the spring Jewish holidays. It will be noted that on Sundays and usually on Saturdays no poultry is unloaded. During the weeks when holidays do not influence the unloads, Wednesday or Thursday is usually the day of heaviest unloads. (*U. S. Dept. Agr.*)

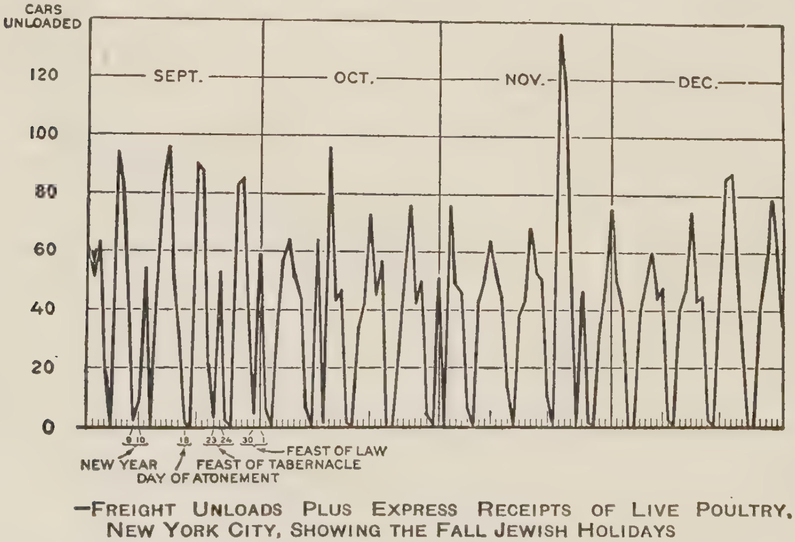


FIG. 198.—Freight unloads plus express receipts of live poultry, New York City, showing the fall Jewish holidays. The receipts normally show a marked increase at the time of or just previous to the holidays of spring and fall. The influence of Thanksgiving and Christmas is also apparent. (*U. S. Dept. Agr.*)

portation of poultry from areas of production to the points of consumption involves many complex problems and the performance of numerous services. (Slocum, 1927.)

Transportation problems in marketing chickens are complicated by the fact that not only are most of the chickens that are reared annually marketed in the fall and early winter months but most of the hens marketed are sold during the late summer and fall after they have finished laying for the season. The Thanksgiving and Christmas requirements demand large shipments at those times. This means that live poultry and refrigerator cars are required in great numbers in a comparatively short season. Then, again, the Jewish holidays, coming in the spring and fall, mean that large shipments of live poultry are required at those particular times.

Figures 195, 196, 197 and 198 show, respectively, the relatively high receipts of dressed poultry in five of the country's leading markets during the months of November and December, the relatively high proportion of live poultry marketed in September, and the effect of the Jewish holidays on the freight and express shipments of live poultry to the New York City market.

Marketing Methods.—Chickens are marketed either alive or dressed, the latter being the more prevalent form. Except for the demand by the Jewish people and a few others for live poultry, it is doubtful if but very few live poultry car lots would be shipped. On the other hand, producers sell a large proportion of their chickens alive to local buyers and poultry packers who fatten, kill and dress the chickens for shipment to the more important markets.

The methods of marketing chickens vary from marketing direct from producer to consumer to marketing through numerous channels of trade as illustrated in Fig. 199. The nearer the producer is to the consumer the more readily can direct selling be practiced and, usually, the better the price received. Because of this, producers in the vicinity of the larger markets have an advantage over producers in sections distant from the better markets.

The proportion of chickens marketed from the producer direct to the consumer is rather small because the practice is limited to producers located near the larger markets and producers who sell chickens on the public markets of the various cities. Nearly all of the chickens sold direct from producer to consumer are dressed chickens that have been fattened.

The manner in which most of the chickens are marketed is described briefly by Slocum (1927) in the following terms:

> The most common method of marketing poultry, where the producer is within easy shipping distance of a large consuming market, is to ship it alive in coops

by express to a poultry dealer who has market outlets and who sells the producers' product for a commission or buys it for his own account at or in relation to prevailing market quotations. A modification of this method may consist of shipping to meat markets, hotels, or other agencies which retail to the consumer either live or dressed poultry. Except in the case of farms which specialize in market poultry, like the duck farms on Long Island, or at the holiday season, very little poultry is actually slaughtered by producers and shipped to market as dressed poultry.

The great bulk of the poultry which supplies the large eastern markets, like New York, is not produced on neighboring farms, but averages a haul, by rail, of 1,000 or more miles from the producing sections. Shipments from individual farms by express for such a distance are impracticable, and so a market channel has gradually been developed whereby car-load lots of live poultry and of dressed poultry are concentrated at shipping points. Briefly traced, this channel from producer to consumer ordinarily is as follows: The farmer sells his poultry alive to a local buyer or he ships it alive in coops by freight or motor truck to a poultry dealer or packer located at a concentrating point, usually a railroad junction. The local buyer may be an independent buyer or an agent or buyer for the packer.

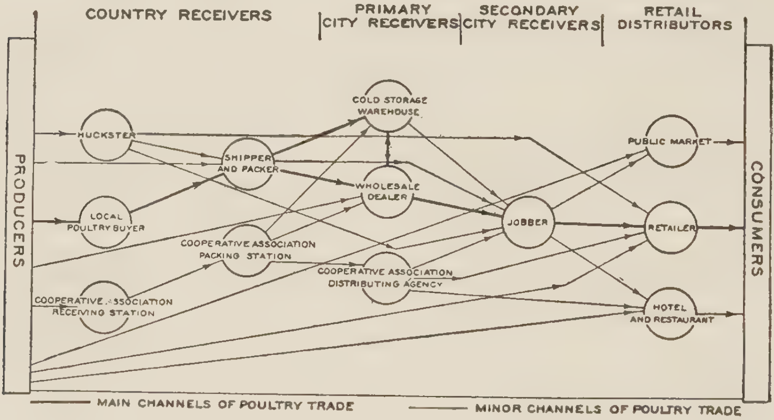

COUNTRY RECEIVERS
PRIMARY CITY RECEIVERS
SECONDARY CITY RECEIVERS
RETAIL DISTRIBUTORS
PRODUCERS
CONSUMERS
HUCKSTER
LOCAL POULTRY BUYER
COOPERATIVE ASSOCIATION RECEIVING STATION
SHIPPER AND PACKER
COOPERATIVE ASSOCIATION PACKING STATION
COLD STORAGE WAREHOUSE
WHOLESALE DEALER
COOPERATIVE ASSOCIATION DISTRIBUTING AGENCY
JOBBER
PUBLIC MARKET
RETAILER
HOTEL AND RESTAURANT
MAIN CHANNELS OF POULTRY TRADE
MINOR CHANNELS OF POULTRY TRADE

FIG. 199.—Channels of poultry trade. (*U. S. Dept. Agr.*)

When received at the packing house the poultry may be sorted out for car-lot shipment alive by fast freight to the final market. Or what is more usual, it may be held on the feeding floor for one or two weeks before it is dressed, chilled, graded, and packed, and then shipped in refrigerator cars to large eastern consuming markets either for immediate consumption or for holding in cold storage for future sale. The dressed-poultry dealers in large markets sell to jobbers or direct to retailers. The business of jobbers is to sell to the retailers, who in turn supply the consumer.

In some of the larger cities an organization composed of dealers, known as the poultry exchange or poultry board, formulates rules governing trading in poultry by its members, establishes grades, and maintains a room where dealers may meet for the purpose of buying and selling and considering matters of general interest.

For further information on the marketing of poultry the reader is advised to consult Pennington (1915), Benjamin (1923), Slocum (1927), Richards, Abell and Rinear (1928), Card (1928*b*), Benton (1928), Beuchel (1929) and Heitz (1929).

Shipping Boxes, Baskets, Barrels and Crates.—Various styles and sizes of boxes, baskets, barrels and crates are used for shipping live and dressed chickens to market. Boxes for shipping dressed chickens include cardboard boxes for parcel-post shipping and wooden boxes for freight and express shipments. Baskets are used for parcel-post shipments and barrels for freight and express shipments of dressed poultry. Wire and wooden crates are used for live poultry shipments.

Paper Boxes.—Corrugated paper-board boxes are commonly used in shipping dressed chickens by parcel post. Each box should be of the proper size for the size of chicken to be shipped. Chickens are usually shipped singly or in pairs. Each chicken should be carefully wrapped in parchment paper, after the head and feet have been separately wrapped The chickens should be cooled thoroughly before being wrapped and packed for shipment. Flohr (1928) points out that strict care should be observed that no odors of any kind are on the packing materials because poultry absorbs odors readily. The boxes should be rigid enough to stand rather rough handling. All parcel-post shipments should be marked Poultry—Perishable.

Baskets.—Splint baskets are sometimes used for shipping one or more dressed chickens by parcel post. Drop handles should be used and corrugated paper board should be used to line the inside of the basket.

Barrels.—Barrels are sometimes used for shipping large numbers of dressed chickens, usually of the lower grades, either by express or by freight.

Wood Boxes.—Most of the dressed chickens sold annually are packed in wooden boxes, 12 to a box. The size of the box is determined by the size of the chicken to be packed. The shape of the box is determined by the style of the pack, whether in a single layer of 2 rows of 6 birds each or in 2 layers of 2 rows of 3 birds each, the single layer of 12 birds being the more desirable pack. The boxes are lined with parchment or waxed paper. The heads of the chickens are wrapped separately and frequently birds of superior quality are wrapped individually in waxed or water-finished fiber paper.

Sometimes chickens shipped in barrels and boxes are packed in ice but the better quality of chickens are not packed in ice but are shipped in refrigerated cases. Poultry not packed in ice should be cooled thoroughly before being packed. After the birds have been dry-packed they should be stored in a chill room at a temperature of 32° F. or as close to that temperature as possible until ready to be shipped. All barrels and boxes should be carefully stenciled, showing the kind of chickens, the gross, tare and net weights.

Crates.—Crates of various designs are used for shipping live poultry. Each crate should be of a sufficient size to accomodate from about 12 to 20 chickens. Too many chickens should not be placed in one crate because some are apt to be suffocated. The crates should be as strong but as light as possible in order to save shipping charges. Different types of crates are used, one being 2 ft. wide and 3 ft. long, one 12 in. high, another the same width and length but 16 in. high, still another being somewhat wider and longer.

SHIPPING LIVE CHICKENS

Live chickens are marketed by producers in their own wagons, trucks or automobiles to local buyers and poultry packing plants or are shipped by express or freight to distant markets. Whatever may be the practice followed, great care should be taken to see that the chickens are crated and shipped in such manner as to ensure their arrival in the best condition possible.

In many cases live chickens are sold direct from the farm to a huckster or to a local buyer who sends his truck around to farms and, upon securing a truck load, the chickens are frequently delivered many miles to a distant market. In these cases the shipper should exercise the greatest care in crating the poultry and arranging the crates in the truck in order to keep the chickens comfortable during the voyage to market.

Chickens in crates being taken to market in trucks, automobiles or wagons should not be subjected to cold winds or some of the birds may catch cold. Nor should the chickens be allowed to become overheated.

Shipping by Express.—Many producers find it to their advantage to ship live chickens by express to distant markets rather than selling locally. When chickens are shipped by express they should be graded in the crates according to color, age, size and condition. Chickens crated according to color always command the buyer's attention more readily than crates of chickens of various colors. Chickens graded according to age and size always have a market advantage over those not so graded. Old birds should never be mixed with young ones and very small birds should not be crated with very large ones. Grading the chickens according to condition is an important factor in commanding the best prices. Cull chickens and those that are sickly should never be shipped to market. The chickens that are in the best fleshing condition should be crated together, leaving the poorly fleshed ones to be crated by themselves.

Producers should study the live chicken market requirements of the market to which they ship their chickens in order that the best shipping days may be determined. Live chickens should not be shipped to arrive at the market on Saturday afternoon because they usually have to be held over until Monday, in which case there is usually excessive shrinkage in weight. Sometimes advantage can be taken of the higher prices prevailing for live chickens at the time of the Jewish holidays, a list of which is given in Table 59.

TABLE 59.—JEWISH HOLIDAYS 1925 TO 1932[1]
(Card, 1928)

Year	Purim	First day Pessach (Passover)	Seventh day Pessach (Last Passover)	First day Shabuoth (Feast of wks.)	Rosh Hashanah (New Year)	Yom Kippur (Day of Atonement)	First day Succoth (Feast of Tabernacles)
1925	Mar. 10	Apr. 9	Apr. 15	May 29	Sept. 19	Sept. 28	Oct. 3
1926	Feb. 28	Mar. 30	Apr. 5	May 19	Sept. 9	Sept. 18	Sept. 23
1927	Mar. 18	Apr. 17	Apr. 23	June 6	Sept. 27	Oct. 6	Oct. 11
1928	Mar. 6	Apr. 5	Apr. 11	May 25	Sept. 15	Sept. 24	Sept. 29
1929	Mar. 26	Apr. 25	May 1	June 14	Oct. 5	Oct. 14	Oct. 19
1930	Mar. 14	Apr. 13	Apr. 19	June 2	Sept. 23	Oct. 2	Oct. 7
1931	Mar. 3	Apr. 2	Apr. 8	May 22	Sept. 12	Sept. 21	Sept. 26
1932	Mar. 22	Apr. 21	Apr. 27	June 10	Oct. 1	Oct. 10	Oct. 15
Kinds of poultry particularly desired	Turkeys	Heavy, fowls, fat ducks, geese	Heavy fowls	Fowls	All kinds	Roosters, spring chickens	Ducks, geese

A certain amount of shrinkage in weight usually takes place when live chickens are shipped to market, the amount of the shrinkage depending upon the shipping distance and the season. The customary amount of shrinkage ranges from about 2 to 15 per cent or more of the original shipping weight, chickens shipped short distances losing less than those shipped great distances. Chickens should never be specially fattened before being marketed alive because the shrinkage is usually excessive.

Where live chickens are shipped such distances as to require 24 hr. or more before reaching the market, a tin of corn that has been thoroughly soaked in water may be nailed on the inside of the crate. The water-soaked corn helps to prevent excessive shrinkage. In the case of chickens

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[1] Adapted from "Marketing of Poultry Products," by E. W. Benjamin and the *Jewish Daily Forward*, New York City.

Table 60.—Proportion of Live Poultry in Car Loads Received at New York by Freight and by Express from the Designated Origins, Average 1923–1924, 1925–1926 and 1927

(Beuchel, 1929)

Origin	Percentage received		
	By freight, per cent	By express, per cent	By freight and express, per cent
Alabama	0.23	......	0.22
Arkansas	0.53	......	0.50
Atlanta, Ga	1.49	......	1.41
Chattanooga, Tenn	5.16	......	4.90
Chicago, Ill	2.79	......	2.65
Connecticut	0.14	1.37	0.21
Georgia	0.17	0.32	0.17
Illinois	16.42	0.04	15.58
Indiana	3.02	0.14	2.88
Iowa	4.17	0.01	3.96
Kansas	10.62	......	10.07
Kentucky	2.24	0.09	2.13
Maine	0.03	4.35	0.25
Maryland	0.09	7.23	0.46
Massachusetts	0.78	6.70	1.08
Michigan	0.20	0.01	0.19
Minnesota	0.34	0.06	0.32
Missouri	24.78	0.03	23.50
Nebraska	7.23	......	6.86
New Hampshire	......	20.18	1.04
New Jersey	......	1.73	0.09
New York	0.17	43.60	2.41
Ohio	4.17	1.22	4.01
Oklahoma	7.68	......	7.28
Pennsylvania	0.59	5.31	0.84
Philadelphia, Pa	0.06	......	0.06
Rhode Island	......	0.46	0.02
South Dakota	0.79	......	0.75
Tennessee	3.76	0.08	3.57
Texas	2.20	......	2.09
Vermont	0.02	2.93	0.17
Virginia	......	4.14	0.21
Wisconsin	0.13	......	0.12
Total	100.00	100.00	100.00

arriving on the market the same day they are shipped they should not be fed during transit but may be fed liberally a few hours before being crated for shipment. Chickens arriving on the market with crops full of feed usually bring a lower price than otherwise or they may be held over until the feed is digested.

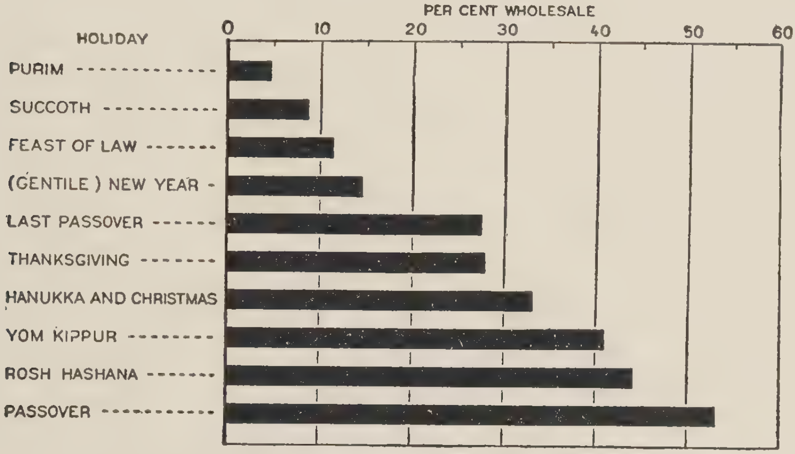

FIG. 200.—Influence of holidays on the weekly wholesale sales of live poultry in New York City. Increases in wholesale sales are expressed as percentages of the average of two weeks prior to a given holiday. The most important Jewish feasts, Thanksgiving, and Christmas demand a larger quantity of live poultry. (*U. S. Dept. Agr.*)

Shipping by Freight.—Freight shipments of live chickens are made either in live-stock cars or in specially constructed live-poultry cars. Closed box cars ordinarily should not be used because there is rarely sufficient ventilation provided for the chickens. The live-poultry car is by far the most satisfactory method of shipping chickens by freight.

Most shipments of live-poultry cars originate at the poultry packing plants, this being the customary practice throughout the Middle West. Some shipments of live-poultry cars are made up at railway stations along a prescribed route where producers bring their chickens to the nearest station, this practice being followed in certain southern states where there are but few poultry-packing plants.

The live-poultry car and the method of handling chickens being shipped in live-poultry cars are described by Slocum (1927) in the following terms:

> Such a car is constructed with an aisle in the center with the coops on each side, one above another, from the floor to the roof. Each coop is provided with a feeding and watering trough. The floors of the coops are removable, which permits two coops to be combined into one of double height for shipping geese or turkeys. The outside of the car is covered with heavy wire screening, which provides good ventilation. In the center a small room for the use of the attendant

who accompanies the shipment is located. Above this is a water tank and beneath is storage space for feed. The birds are more comfortable in such a car, and the attendant can give them better care and do it more easily. A live-poultry car has 128 coops or decks and has a capacity of about 4,600 chickens, which will weigh approximately 18,000 lb. net.

Live poultry in such cars may be in transit from two to three days to a week or more. To reduce shrinkage in weight during shipment and to prevent losses from death, the attendant must give the birds good care and must feed and water them regularly. The last full feed is given on the day before the car is to be unloaded and only a partial feed is given on the morning of unloading so that the poultry will not be overcropped. In New York City, there is a regulation of the department of health which prohibits the sale of poultry with crops averaging more than 2 oz. in weight. As a result, all cars of live poultry arriving for that market are inspected under the supervision of the U. S. Department of Agriculture both for condition of health and for size of crop before they can be unloaded. Changes in weight during transit may vary considerably and may represent a loss or a gain, depending upon the health and condition of the poultry, the skill of the carman, and weather conditions.

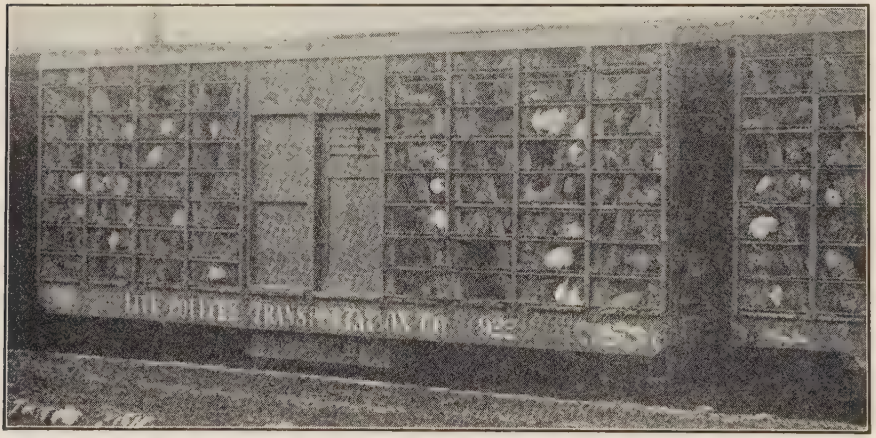

FIG. 201.—Live poultry on its way to New York. (*Photograph by U. S. Egg and Poultry Magazine.*)

Live-poultry cars are supposed to be cleaned between shipments and to be disinfected when necessary by the company operating them, but this is not always possible. When a car is received on the shipper's switch in a dirty condition, it should be given a good cleaning to prevent losses from disease and insanitary conditions.

Grading Live Chickens.—Producers should appreciate the fact that live chickens graded according to color, age, and condition always command a higher price than ungraded chickens. The Bureau of Agricultural Economics of the U. S. Department of Agriculture has proposed tentative classes and subclasses for live poultry, as given below.

TABLE 61.—TENTATIVE U. S. CLASSES AND SUBCLASSES FOR LIVE POULTRY

Class	Subclass	Weight requirements	Description	Breed requirements
U. S. broilers	Light	¾ to 1¼ lb.	Young, soft-meated chickens with breast bones flexible at the points	All breeds except the Mediterraneans
	Medium	Over 1¼ and not over 2 lb.		
	Heavy	Over 2 and not over 2½ lb.		
U. S. Mediterranean broilers	Light	1¼ and under	Young, soft-meated chickens with breast bones flexible at the points	All Mediterranean breeds
	Heavy	Over 1¼ and not over 2½ lb.		
U. S. chickens	Light	Over 2½ and not over 4 lb.	Young, soft-meated chickens with breast bones flexible at the points	All breeds except the Mediterraneans
	Heavy	Over 4 lb.		
U. S. Mediterranean chickens		Over 2½ lb.	Young, soft-meated chickens with breast bones flexible at the points	All Mediterranean breeds
U. S. stags		None	Male chickens which have begun to get hard meated, coarse and stringy and showing nearly full comb development and well-developed stubby spurs. Ends of breast bones no longer flexible	All breeds
U. S. capons	Light	5 lb. and under	Unsexed male birds showing practically no comb or spur development and with profuse tail, saddle and hackle plumage	All breeds
	Heavy	Over 5 lb.		
U. S. fowl	Light	4 lb. and under	Mature female chickens	All breeds except the Mediterraneans
	Medium	Over 4 and not over 5 lb. except that thin fowl weighing over 5 lb. shall be included in this subclass	Mature female chickens. If well fleshed may be designated also as "fat"	All breeds except the Mediterranean
	Heavy	Over 5 lb.	Mature female chickens must be well fleshed	All breeds except the Mediterraneans
U. S. Mediterranean fowl		None	Mature female chickens	All Mediterranean breeds
U. S. general run fowl		42 lb. and over per dozen. No weight limitation for individual fowl	Mature female chickens	All breeds
U. S. old cocks		None	Mature male chickens having well-developed combs and spurs	All breeds

All live poultry shall be free from any disease or other condition which renders it unfit for human food. Extreme emaciation shall be taken to be evidence of a diseased condition which renders the bird unfit for human food.

SHIPPING DRESSED CHICKENS

Producers who sell direct to consumers or on the public markets of the larger cities usually sell their chickens dressed rather than alive. On the other hand, except for the demand for live chickens for the Jewish trade and certain other people who demand fresh-killed chickens, most of the chickens shipped to the markets of the consuming centers are shipped in the dressed form. A dressed chicken means, of course, one that has been killed and plucked.

Dressed chickens are shipped in the fresh condition or after they have been held in storage for some time. In recent years dressed chickens that are drawn and frozen immediately after being dressed are being shipped direct to retailers and consumers.

Killing and Plucking.—Chickens should be deprived of feed for about 24 hr. before being killed. This will clean out feed from the crops and intestines. The dressed birds also will keep longer, and will be of better quality. During the period they are not fed they should have water, which will wash feed particles out of the digestive tract.

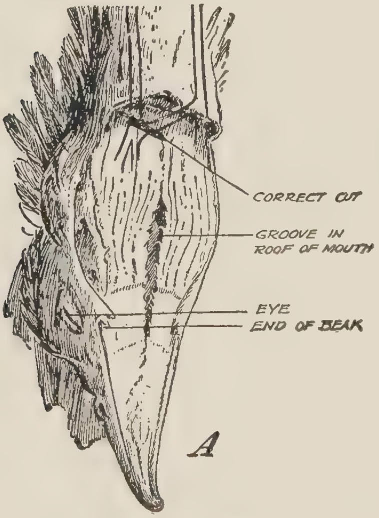

FIG. 202.—Good bleeding depends upon making the cut in the right place. (*U. S. Dept. Agr.*)

Bleeding.—One of the best ways to kill a fowl is to bleed it by severing the arteries in the neck, as shown in Fig. 202. From the ceiling of the room in which the killing is to be done the fowl is suspended by the feet at about the height of the shoulder of the plucker. Any stout cord with a short stick in the end will do to wrap around the bird's feet. In poultry packing plants shackles made of stout wire are used.

A particular kind of killing knife is desirable. The blade of the knife is a heavy piece of steel, about 2 in. long, ¼ in. wide and ⅛ in. thick on the back. It should be ground to a sharp point with a straight cutting edge, the slope of the point being taken from the back edge rather than from the front. The handle should be fairly stout, so that it can be grasped readily. A strong, sharp jackknife could be used to advantage.

The head of the fowl is taken in the left hand and the knife in the right hand. With the thumb and forefinger of the left hand the mouth is forced open by pressure and the knife is inserted into the mouth with the blade pointing toward the back of the head. The knife is then forced up to the juncture of the head and neck where the arteries come down on each side of the neck; these are severed and the fowl bleeds freely. For a left-handed person the operation would be performed in the opposite way.

Piercing the Brain.—Immediately afterwards the knife is forced into the roof of the mouth. This is done by withdrawing the knife from the juncture of the head and neck and turning it over so that the back of the knife passes along the upper beak into the groove in the roof of the mouth. It is then immediately forced into the brain cavity so that the brain is pierced. When this is done properly the bird will squawk and it will also make a convulsive movement which tends to loosen the feathers in the feather muscles. If the brain has not been properly pierced the feathers are hard to pluck and the skin is frequently torn badly. Poorly bled chickens frequently show reddened areas over the body, especially along the neck and around the thighs.

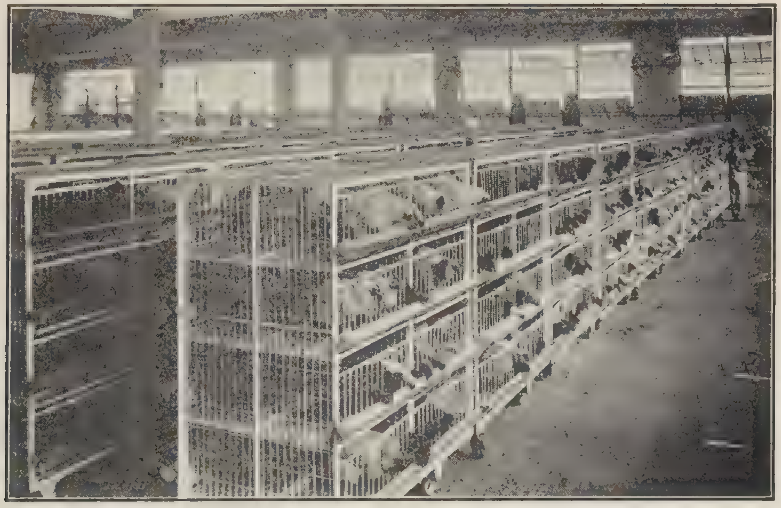

Fig. 203.—A modern poultry fattening plant, providing proper lighting and adequate ventilation. (*Photograph by Swift and Company.*)

For the Jewish Trade.—Chickens killed for the orthodox Jewish trade must be killed under the supervision of a rabbi, such chickens being known as "kosher killed." One of the essential features in kosher killing is that the jugular vein and the trachea both must be severed. After the chicken's throat has been cut the killer must pass his thumb forward from the rear of the neck to push out the end of the trachea to be sure that this has been completely severed. To remove the knife from the cut and replace it makes the chicken non-kosher. Diseased chickens and those having broken bones are not acceptable for kosher killing.

Dry Plucking.—For many years the most common method of plucking chickens was by dry plucking, the body feathers being removed by a rubbing motion of the hand and the tail and wing feathers pulled out. Dry picking must be done immediately the bird is killed and while the body is still warm. Circular 42 of the U. S. Department of Agriculture

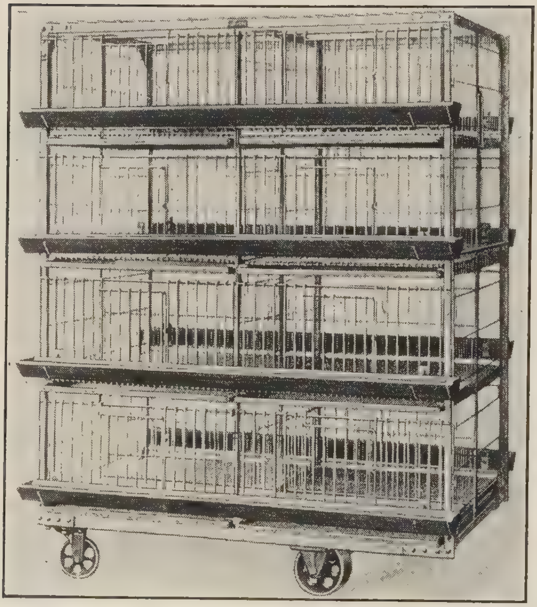

Fig. 204.—A modern fattening battery for fattening poultry on a commercial scale. (*Photograph by Union Steel Products Co.*)

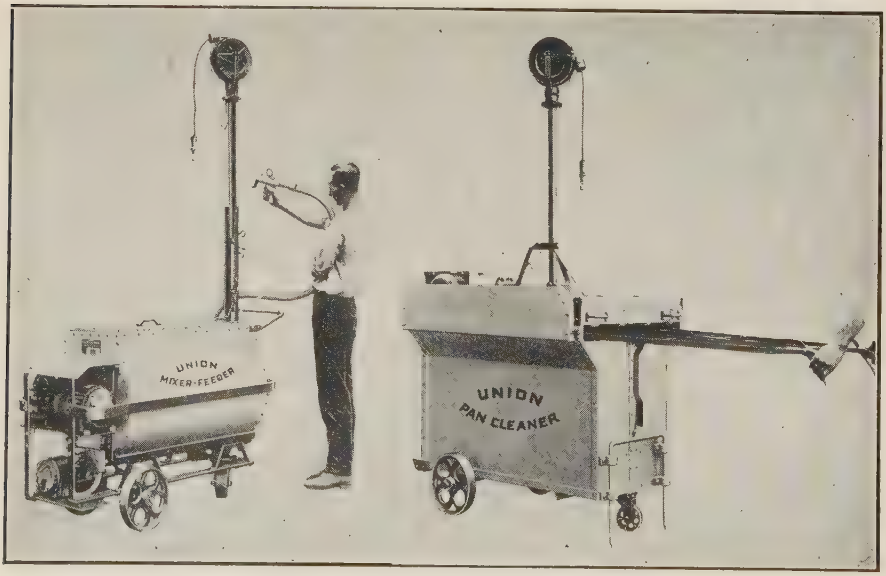

Fig. 205.—A modern machine for mixing fattening rations and feeding them to batteries in fattening stations. A labor saving device.

Fig. 206.—A modern machine which enables the ready cleaning of the droppings pans in fattening batteries. Such a piece of apparatus makes for economy in fattening station operations. (*Photographs by Union Steel Products Co.*)

gives the following order of plucking the feathers: tail, large wing feathers, breast and sides, thighs, legs, soft body feathers, back and hip feathers, neck and small feathers on the wings. Then each bird should be gone over carefully for pin feathers. The head and feet should be wiped carefully with a damp cloth. The bird should then be hung on racks in a chilling room as near freezing as possible, but not below 32° F., for at least 24 hr. before being packed.

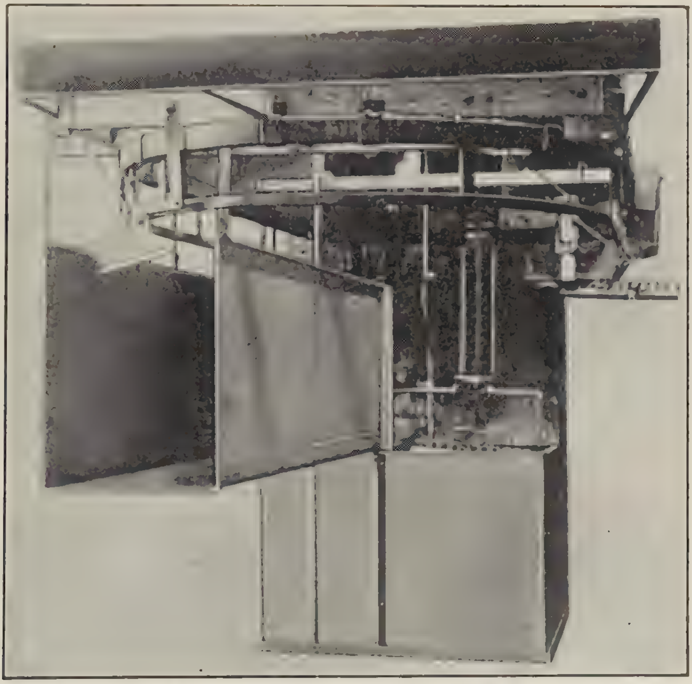

Fig. 207.—Chickens are automatically dipped in hot water by this modern machine before being plucked by the "semi" or "slack-scald" method of plucking chickens. (*Photograph by Union Steel Products Co.*)

Wet Plucking.—Chickens are also plucked by dipping them in hot water, which tends to loosen the feathers and makes plucking easier. There are two methods employed, the slack-scald or semiscald method and the ordinary scald method. The latter method should be used only in the case of chickens being consumed locally, immediately after being killed. Both methods of scalding are described by Heitz (1929) in the following terms:

> During recent years a new method of dressing poultry, known as semiscalding, has been practiced by some of the largest poultry packers. This process is practically the same as scalding, except that the temperature of the water used is much lower, ranging from 126 to 130° F. The birds are immersed for a period

of 30 to 35 sec. The feathers are picked off, instead of rubbed off as in the case of scalded poultry, and a result resembling dry picking is obtained. It has the advantage over dry picking, in that it is a much quicker method and removes many pin feathers that could not be removed without this partial scalding. Poultry plucked by this method should be thoroughly dried before being frozen, or mold growth is likely to occur. If proper precautions are taken, however,

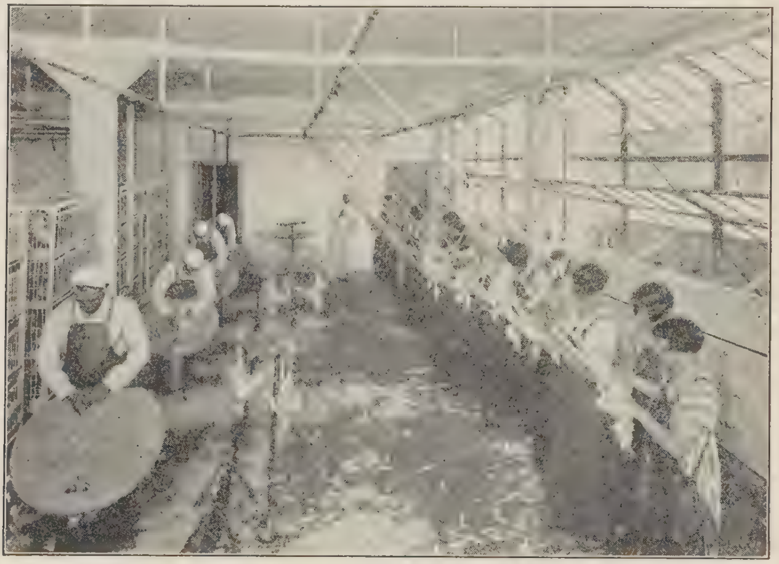

FIG. 208.—Dressing chickens in a modern poultry packing plant. (*Photograph by Swift and Company.*)

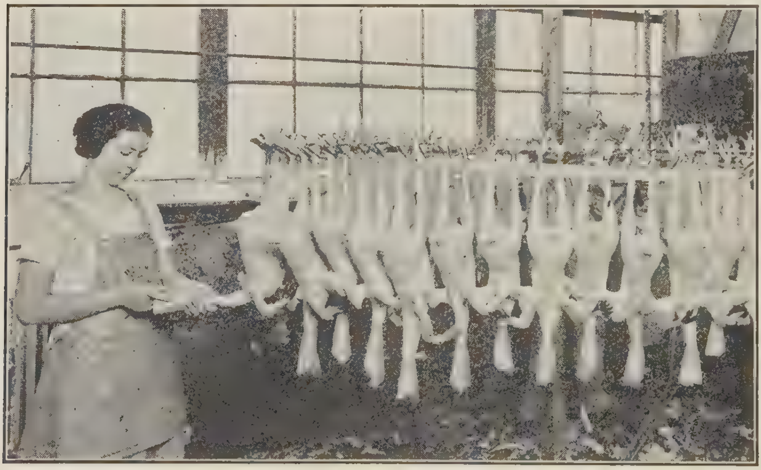

FIG. 209.—Wrapping the heads of dressed chickens with parchment paper. (*Photograph by U. S. Egg and Poultry Magazine.*)

such poultry seems to keep in storage as well as that which is plucked by the dry method.

If poultry is scalded it should be immersed in water at a temperature from 160 to 170° F. and should remain there only until the feathers will rub off easily. Too long scalding, or too hot water will tend to cook the skin and lower the keeping quality of the bird. If the head and feet are not immersed in the scalding water the carcass will have a much better appearance than if it is completely dipped.

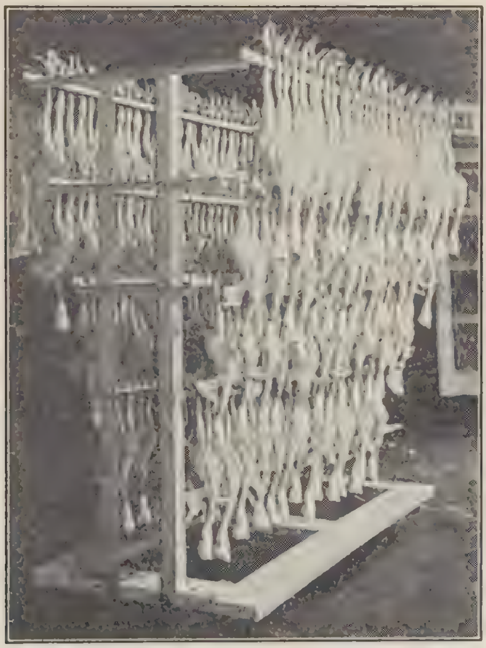

Fig. 210.—Dressed chickens with heads wrapped suspended on a cooling rack. (*Photograph by U. S. Dept. Agr.*)

As soon as the feathers have been removed, the carcass should again be placed in water of the same temperature as that used in scalding, and then quickly removed and placed in clean, cold, running tap water (but it should not be iced). This causes the bird to puff or plump and gives it a much better appearance. Poultry should be left in the cold water for 3 or 4 hr. and then taken out and placed in ice water or hung in a cooler until the inside temperature of the heaviest fowl is reduced at least to 35° F. The skin of water-chilled poultry that has not been thoroughly dried shows deterioration a short time after storing. Small spots of dry, scaly skin will be noticeable and the carcass will have the appearance of being blistered. This is especially true of scalded poultry, as the protective qualities of the skin are greatly reduced by the hot water.

The slack-scald or semiscald method of plucking chickens has become very popular in poultry-packing houses largely because it saves time over the dry-plucking method. Machinery that automatically dips the birds in hot water is used in many cases and this does away with the need for a portion of the number of persons ordinarily required to dry pluck chickens.

Composition.—The composition of the skin and other parts of dry-plucked and slack-scald-plucked chickens has been studied by Pennington (1928). It was found that chickens plucked by the slack-scald method were higher in the water content of the skin, lower in the fat content of the skin, higher in solids not fat in the skin, higher in the acidity of fat and slightly higher in the percentage of ammonia nitrogen in the flesh than in dry-plucked chickens. These differences were interpreted by Miss Pennington to mean that the keeping qualities of the chickens plucked by the slack-scald method were inferior to those plucked dry. At the same time, chickens plucked by the slack-scald method seem to be giving satisfaction in the trade.

Drawing.—Concerning the drawing of dressed chickens, Heitz (1929) has the following to say:

> During the last two or three years, a new method of marketing poultry by preparing it full drawn has come into considerable use. After the poultry is dressed at the poultry plant, the head, feet, and entrails are removed. The giblets are cleaned, wrapped in parchment or waxed paper, and are replaced in the body cavity. The entire carcass is frozen by a quick freezing process as soon as it is prepared, and is marketed in a frozen state. A saving in freight is accomplished by removal of the inedible portions at the country point and the saving in containers and storage charges are items of importance. Proponents of this method claim that the poultry meat is much sweeter and finer flavored than is the case when poultry is shipped without the removal of the entrails.

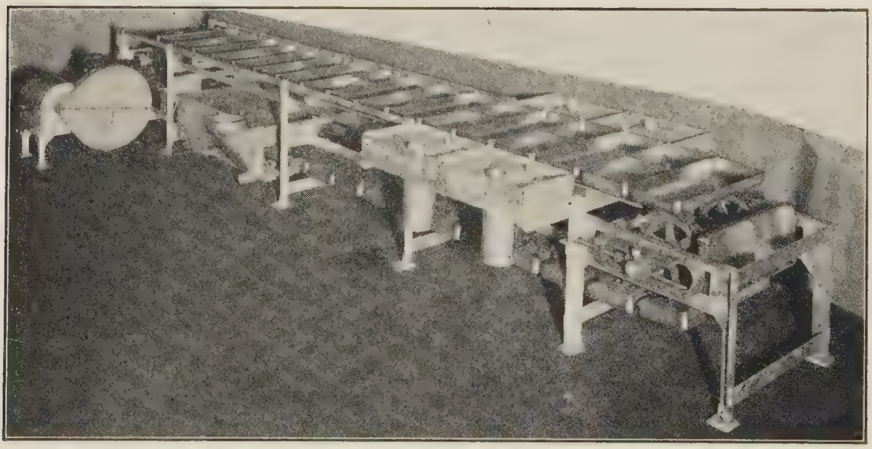

FIG. 211.—Mechanical combination poultry inspection and eviscerating table for the inspection of drawn poultry. Note the revolving table top consisting of pans for holding the viscera or offal and the drawn birds. (*Photograph by Mechanical Manufacturing Co.*)

TABLE 62.—AVERAGE WEIGHTS OF PARTS OF CARCASS OF WHITE PLYMOUTH ROCK COCKERELS, PULLETS, AND CAPONS KILLED AT DIFFERENT WEIGHTS, EXPRESSED IN PERCENTAGE OF THE EMPTY WEIGHT
(Mitchell, Card and Hamilton, 1926)

Kind of bird	Approximate slaughter weight, pounds	Average age, days	Average empty weight, grams	"Fill," per cent	Feathers, per cent	Blood, per cent	Head, per cent	Shanks and feet, per cent	Heart, per cent	Liver, per cent	Kidneys, per cent	Pancreas, per cent
Cockerel	0.5	29	216	6.8	4.3	4.2	5.6	5.1	0.80	3.7	....	0.51
Cockerel	1.0	43–57	423	5.8	4.0	4.7	4.5	5.4	0.68	3.7	1.1	0.42
Cockerel	1.5	71	637	5.3	5.0	4.6	4.2	5.7	0.58	3.0	0.83	0.33
Cockerel	2.0	103	967	2.6	4.8	4.8	3.4	5.8	0.48	2.3	0.64	0.30
Pullet	2.0	73	915	4.8	7.2	3.7	3.1	5.0	0.49	2.5	0.68	0.31
Cockerel	3.0	117	1,305	4.1	6.4	4.1	3.3	6.3	0.43	2.3	0.60	0.22
Pullet	3.0	94	1,293	3.7	8.4	3.2	2.9	4.7	0.42	2.2	0.63	0.22
Capon	3.0	88	1,315	4.4	6.5	4.1	3.0	5.8	0.46	2.4	0.64	0.21
Cockerel	4.0	169	1,725	3.4	7.8	4.2	3.1	5.5	0.42	2.1	0.50	0.21
Pullet	4.0	189	1,787	2.6	8.5	3.3	2.7	3.7	0.48	1.7	0.55	0.24
Capon	4.0	170	1,656	2.7	8.5	4.0	3.1	5.4	0.42	2.2	0.62	0.22
Cockerel	5.0	177	2,156	3.6	8.1	4.4	2.9	5.2	0.43	2.0	0.53	0.23
Pullet	5.0	219	2,245	3.7	7.5	3.5	2.4	3.6	0.45	1.9	0.62	0.22
Capon	5.0	180	2,225	2.6	8.0	4.3	2.6	5.0	0.41	2.2	0.54	0.22
Cockerel	6.0	250	2,509	2.9	8.1	4.2	2.8	4.5	0.45	2.0	0.52	0.18
Capon	6.0	215	2,599	3.5	7.8	3.5	2.3	5.0	0.42	1.9	0.54	0.22
Cockerel	7.0	324	3,182	2.2	5.8	4.7	3.2	4.1	0.66	1.3	0.39	0.17
Capon	7.0	240	3,093	3.0	7.2	3.7	2.3	4.0	0.44	2.3	0.52	0.17

TABLE 62.—AVERAGE WEIGHTS OF PARTS OF CARCASS OF WHITE PLYMOUTH ROCK COCKERELS, PULLETS, AND CAPONS KILLED AT DIFFERENT WEIGHTS, EXPRESSED IN PERCENTAGE OF THE EMPTY WEIGHT (*Continued*)
(Mitchell, Card and Hamilton, 1926)

Kind of bird	Spleen, per cent	Lungs, per cent	Testicles, per cent	Digestive tract, per cent	Skin, per cent	Neck, per cent	Legs above hock, per cent	Wings, per cent	Torso, per cent	Total bone in dressed carcass, per cent	Total flesh and fat in dressed carcass, per cent	Total flesh, fat, and edible viscera,[1] per cent
Cockerel	0.19	0.60	0.05	13.9	6.5	3.7	16.2	6.5	21.3	18.1	25.0	34.5
Cockerel	0.21	0.58	0.04	14.2	7.8	3.5	18.0	6.4	22.5	17.0	31.7	41.1
Cockerel	0.27	0.52	0.03	12.6	7.7	3.3	19.0	6.3	22.4	17.1	33.0	41.5
Cockerel	0.20	0.43	0.03	11.9	7.3	3.9	20.2	6.4	22.0	19.1	33.4	40.7
Pullet	0.26	0.46	....	11.4	8.0	3.8	18.3	6.2	24.0	17.6	34.0	41.9
Cockerel	0.21	0.51	0.02	10.0	7.0	3.7	21.5	6.7	23.4	18.7	36.1	43.0
Pullet	0.23	0.51	....	10.1	8.0	3.5	20.0	6.3	26.7	17.3	38.4	45.3
Capon	0.21	0.52	....	10.0	7.5	3.6	20.3	6.5	25.2	18.1	36.9	44.0
Cockerel	0.17	0.53	0.09	8.6	7.4	3.7	22.1	6.6	24.6	19.1	36.0	42.2
Pullet	0.18	0.45	....	9.4	9.2	2.9	19.3	5.4	29.3	15.0	41.0	47.0
Capon	0.25	0.59	....	9.1	8.2	3.5	20.9	6.3	24.5	19.3	33.8	40.4
Cockerel	0.19	0.55	0.06	7.2	8.1	3.4	22.1	5.9	25.0	18.7	36.9	43.3
Pullet	0.21	0.40	....	8.6	10.0	2.7	19.0	5.4	30.2	14.7	41.8	47.6
Capon	0.21	0.50	....	8.7	8.6	3.1	21.3	5.9	25.4	17.6	36.6	42.4
Cockerel	0.16	0.45	0.26	7.9	7.6	3.4	22.2	5.9	26.4	16.7	40.2	45.9
Capon	0.23	0.49	....	9.0	8.8	3.2	20.4	5.7	28.3	17.0	39.3	45.0
Cockerel	0.11	0.43	1.04	5.8	8.5	3.4	24.9	5.7	26.9	16.0	45.0	50.4
Capon	0.21	0.42	....	7.5	8.8	2.9	19.7	5.9	31.3	16.1	44.0	49.7

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[1] Including heart, liver, gizzard, and kidneys.

If the carcass is hard frozen immediately after being prepared, and if well wrapped in parchment paper, the keeping qualities in storage seem to compare favorably with that of undrawn poultry.

Brown (1929) describes a new machine that automatically removes the head and feet and eviscerates (removes the crop and intestines) a chicken in one operation. It is possible that in the near future practically all dressed chickens will be drawn before being packed for shipment.

Percentages of the various parts of chickens when dressed and drawn for market, such as feathers, head, feet, and intestines and percentages of the drawn and edible portions of live chickens are given on page 8.

The proportions of different parts of the carcass and empty weights of White Plymouth Rock pullets, cockerels and capons, as determined by Mitchell, Card and Hamilton (1926), are given in Table 62.

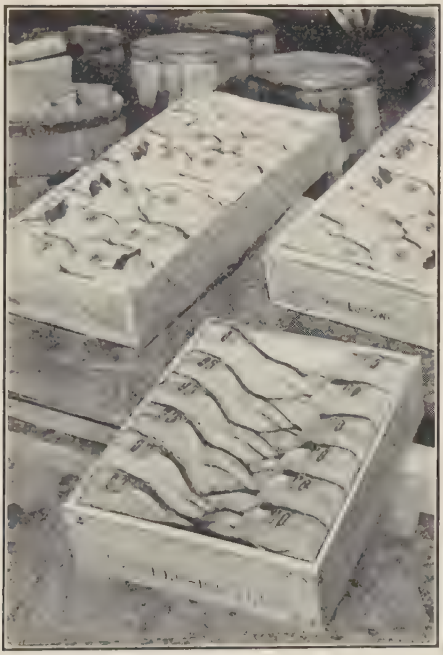

Fig. 212.—Dressed fowl and broilers packed in boxes. (*Photograph by U. S. Egg and Poultry Magazine.*)

Trussing and Boning.—The trussing and boning of drawn chickens is an excellent way of preparing poultry meat for the table. The manner in which the tendons and bones are removed has been fully discussed by Lippincott (1927). The operation requires considerable skill in order to avoid tearing the skin. The only openings made in the skin are at the shoulder, vent and at the ends of the "drumsticks." When properly deboned the meat portion is stuffed with dressing and roasted.

Table 63.—Tentative Specifications for U. S. Standards and Grades of Dressed Chickens

Classes	U. S. grades	Quality specifications of individual birds	Grade tolerance	Weight specifications				
				Weight range per bird		Weight per dozen birds, pounds		
				Min.	Max.	Min.	Avg.	Max.
Broilers........	U. S. Prime or No. A 1	Young, soft-meated, full-fleshed birds of uniform pack and color, well bled, free from deformities, torn skin, pin feathers, bruises or other dressing defects	Not to exceed two "line" birds permitted in each dozen	None 1# 7 oz. 1# 11 oz. 2# 2 oz.	1# 6 oz. 1# 10 oz. 2# 1 oz. 2# 8 oz.	None 16 21 26	.... 18 23 28	16 20 25 30
	U. S. Choice or No. 1	Young, well-fleshed, well-dressed birds free from deformities; or full-fleshed birds that show slight deformities or slight dressing defects						
	U. S. Medium or No. 2	Poorly fleshed, well-dressed birds; or well-fleshed birds that show slight deformities and dressing defects						
	U. S. Common or No. 3	Edible birds inferior to U. S. medium broilers	None	All birds of this grade may be packed together irrespective of their weight				
Fryers..........	U. S. Prime or No. A 1	Same as for U. S. prime broilers	Not to exceed two "line" birds permitted in each dozen	2# 9 oz. 3# 1 oz.	3# 3# 8 oz.	31 37	33½ 39½	36 42
	U. S. Choice or No. 1	Same as for U. S. choice broilers						
	U. S. Medium or No. 2	Poorly fleshed, well-dressed birds; or well-fleshed birds that show slight deformities and dressing defects and/or very slight comb or spur development						
	U. S. Common or No. 3	Edible birds inferior to U. S. medium fryers	None	All birds of this grade may be packed together irrespective of their weight				
Roasters.......	U. S. Prime or No. A 1	Same as for U. S. prime broilers	Not to exceed two "line" birds permitted in each dozen	3# 9 oz. 4# 4# 8 oz. 5# 5# 8 oz.	3# 15 oz. 4# 7 oz. 4# 15 oz. 5# 7 oz. None	43 48 54 60 66	45 50½ 56½ 62½	47 53 59 65 none
	U. S. Choice or No. 1	Same as for U. S. choice broilers						
	U. S. Medium or No. 2	Same as for U. S. medium fryers						
	U. S. Common or No. 3	Edible birds inferior to U. S. medium roasters	None	All birds of this grade may be packed together irrespective of their weight				

Stags	U. S. Prime or No. A 1	Young, well-fleshed male birds showing considerable maturity, spurs developing but soft, flesh slightly coarse, free from deformities, torn skin, pin feathers, bruises or other dressing defects	Not to exceed two "line" birds permitted in each dozen	None 3# 4# 5# 6#	3# 3# 15 oz. 4# 15 oz. 5# 15 oz. None	None 36 48 60 72	.... 41½ 53½ 65½	36 47 59 71 none
	U. S. Medium or No. 2	Young, poorly fleshed, well-dressed male birds, showing considerable maturity, flesh darkened and coarse; or well-fleshed birds that show slight deformities or dressing defects						
	U. S. Common or No. 3	Edible birds inferior to U. S. Medium stags	None	All birds of this grade may be packed together irrespective of their weight				

TABLE 64.—TENTATIVE SPECIFICATIONS FOR U. S. STANDARDS AND GRADES OF DRESSED CHICKENS

Classes	U. S. grades	Quality specifications or individual birds	Grade tolerance	Weight specifications				
				Weight range per bird		Weight per dozen birds, pounds		
				Min.	Max.	Min.	Avg.	Max.
Cocks	U. S. Prime or No. A 1	Mature, well-fleshed male birds, free from deformities or dressing defects	Not to exceed two "line" birds permitted in each dozen	None	4#	None	....	48
	U. S. Medium or No. 2	Mature, poorly fleshed, well-dressed male birds dark and coarse meated, or well-fleshed birds that show slight deformities or dressing defects		4#	4# 15 oz.	48	53½	59
				5#	5# 15 oz.	60	65½	71
				6#	None	72	....	None
	U. S. Common or No. 3	Edible birds inferior to U. S. medium cocks	None	All birds of this grade may be packed together irrespective of their weight				
Capons	U. S. Prime or No. A 1	Full-fleshed caponized cockerels, soft-meated, comb and spurs undeveloped, free from deformities or dressing defects	Not to exceed two "line" birds permitted in each dozen	None	6#	None	....	72
	U. S. Choice or No. 1	Well-fleshed, well-dressed caponized cockerels, free from deformities, or full-fleshed caponized cockerels that show slight dressing defects or deformities; or well-fleshed poorly caponized cockerels, or "slips" free from deformities or dressing defects		6#	6# 15 oz.	72	77½	83
	U. S. Medium or No. 2	Poorly fleshed, well-dressed caponized cockerels, or well-fleshed caponized cockerels and "slips" that show slight deformities or dressing defects		7#	7# 15 oz.	84	89½	95
				8#	8# 15 oz.	96	101½	107
				9#	9# 15 oz.	108	113½	119
				10#	None	120	.....	None
	U. S. Common or No. 3	Edible birds inferior to U. S. medium capons	None	All birds of this grade may be packed together irrespective of their weight				
Fowls	U. S. Prime or No. A 1	Mature, full-fleshed female birds, uniform pack and color, free from excessive abdominal fat, excessive scaly legs, deformities or dressing defects	Not to exceed two "line" birds permitted in each dozen	None	3#	None	....	36
	U. S. Choice or No. 1	Mature, well-fleshed, well-dressed female birds free from deformities; or full-fleshed birds that show slight dressing defects or deformities or excessive abdominal fat		3#	3# 7 oz.	36	38½	41
	U. S. Medium or No. 2	Mature, poorly fleshed, well-dressed female birds; or well-fleshed birds that show slight deformities or dressing defects		3# 8 oz.	3# 15 oz.	42	44½	47
				4#	4# 7 oz.	48	50½	53
				4# 8 oz.	4# 15 oz.	54	56½	59
				5#	5# 7 oz.	60	62½	65
				5# 8 oz.	None	66	....	None
	U. S. Common or No. 3	Edible birds inferior to U. S. medium fowls	None	All birds of this grade may be packed together irrespective of their weight				

Grading Dressed Chickens.—Dressed chickens of one color, size and quality, and as nearly uniform in appearance as possible, should be packed together. Dressed chickens are sold largely on appearance. If chickens of poor quality or with torn skins are packed with chickens of superior quality and finish the average price of all is lowered.

Table 65.—Classification, Grades, General Grading Requirements and Recommendations for Packing Dressed Poultry

Poultry shall be classified according to age, weight and sex as follows:

Chickens:
- A. Young
    1. Broilers
    2. Fryers
    3. Roasters
    4. Stags
    5. Capons
- B. Old
    1. Fowl
    2. Cocks

Poultry shall be classified according to method of plucking, finishing, condition and pack as follows:

- I. Plucking:
    1. Scalded
    2. Semiscalded
    3. Dry picked
- II. Dressing:
    1. Drawn
    2. Undrawn
- III. Finishing:
    1. Milk fed
    2. Grain fed
- IV. Condition:
    1. Fresh dressed
    2. Fresh hard chilled
    3. Frozen
- V. Packing:
    1. Dry
    2. Iced

Grades of Dressed Poultry

Poultry shall be graded according to quality and condition as follows:

U. S. Prime or No. A1	U. S. Choice or No. 1	U. S. Medium or No. 2	U. S. Common or No. 3

For stags and cocks only three grades are provided, viz: U. S. Prime or No. A1, U. S. Medium or No. 2, and U. S. Common or No. 3, birds of that quality which for other classes would be graded U. S. Choice or No. 1, being included in the grade of U. S. Prime for these classes.

General Grading Rules

1. Packages must be clean, odorless and of sufficient strength to carry poultry in good condition.

2. A lot of poultry of a designated weight shall average nearer to the average weight than to the minimum or maximum.

3. Where the crop is not empty the bird shall be classed in a lower grade.

4. Poultry with dirty feet, head or body shall be classed in a lower grade.

5. All birds must be free from any condition as evidenced by external appearance which would render them unwholesome for food.

6. Poultry that is dark or blistered or skin dried from freezing shall not be graded as U. S. Prime.

Recommendations for Packing Dressed Poultry

1. All poultry should be box packed.
2. Packages should be lined with good quality 30-lb. parchment paper, except where birds are individually wrapped.
3. Packages should be of uniform size, color and markings.
4. The net weight should be marked on the box, also the number of birds when other than 12.
5. Barrel packed poultry should show the gross, tare and net weights.
6. The method of plucking should be marked on the package, as (D.P.) dry picked, (Sc.) Scalded (S.S.) Semiscalded.
7. The U. S. grade should be stenciled on the boxes.
8. Any grade name may be supplemented by such breed, variety or other descriptive terms as may more completely describe the lot of poultry, as U. S. Prime White Wyandotte broilers.
9. Private brands and class numbers may be put on package in addition to the U. S. grades.
10. Stencil marks on boxes should be at least ¾ in. high.
11. Cleats 2 by ¾ in. should be used on all double-layer boxes.
12. All poultry except turkeys should be packed breast up.
13. All heads should be wrapped.
14. Thirty-pound water finish film paper should be used for wrapping heads.
15. All poultry should be packed in single-layer boxes except turkeys and geese.
16. All poultry should be bled through the mouth.
17. All feathers should be removed from capons.

CANNED CHICKEN AND CHICKEN SOUP

The business of cooking chickens commercially and sealing them in cans has increased considerably during the past few years. The chickens may be canned individually or in pieces or in the form of such products as curried, boned, potted and deviled chicken. Canned chicken soup is another product that finds a ready sale.

Factory Canning.—Chickens are canned in the half and whole form. For this purpose some of the best grades are used. Also the canning of chicken enables poultry packers and manufacturers to dispose of certain kinds of chickens, such as those with torn or scalded skins and thin ones, to be marketed to good advantage.

Home Canning.—The home canning of chicken is briefly discussed by Benjamin (1923)[1] as follows:

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[1] Benjamin, Earl W., "Marketing Poultry Products." By permission of John Wiley & Sons, Inc., publishers.

Poultry canning may be easily done in the home and the canned meat is delicious. A chicken weighing 2 lb. when dressed should make a pint can of solid meat and a pint of stock thick enough to jelly; one weighing 3 lb. should fill a 1½-pt. can.

Chicken can be successfully canned by the following method:

Free the meat from the bone, and cut it in pieces of such a size that they will go into the jars easily. Pack the raw meat solidly into tested, clean, glass jars, filling the jars to within ¾ in. from the top. Sprinkle over the top of the meat ½ teaspoonful of salt for each pint of meat. Add no water. Celery leaves, onion, pepper, or other seasonings may be added if desired. Use new rubbers of good quality. Place the cover on the top of the jar, and adjust, but do not fasten, the upper wire clamp, or if a Mason jar is used, partly screw on the cover. Place the jars on a rack in a tightly covered container, such as a wash boiler or a sap bucket, in which there is warm water that reaches to within about 1 in. from the tops of the jars. Sterilize the meat by cooking it for 4 to 5 hr., beginning to count the time when the water around the jars reaches the boiling point. A steam cooker is particularly convenient, and a pressure canner reduces the sterilization period; but a wash boiler or a sap bucket answers the purpose satisfactorily. Before removing the cans from the sterilizer, complete the sealing of each jar by adjusting the lower wire of the clamp or, in the case of the Mason jar, by screwing the top tight. Keep the jars in a cool, dark place.

Chicken stock is made from the bones and trimmings of the chicken, which are covered with cold water, salted, and slowly simmered until the flesh drops in shreds from the bones, and the liquid, or stock, is concentrated. Seasoning, such as onion and a bit of celery leaf, may be added. Strain the stock if desired, reheat it, and boil for 10 min. Pour it into sterilized jars, and sterilize it, as described above, for 1 hr. on two successive days.

Many people prefer to have the poultry flesh left on the bones; when canned in this way it has a delicious flavor, and the cuts may be served very satisfactorily. One housewife obtains excellent results by packing the poultry, cut as for fricassee, into glass jars, adding a teaspoonful of salt for each quart, and filling the can to the top with boiling water. The cans are then sterilized in a steam cooker.

CHAPTER XXX

BY-PRODUCTS OF THE CHICKEN INDUSTRY

The by-products of the chicken industry include principally feathers and manure, both of which have considerable value, and dead birds and offal from poultry packing and canning plants. The principal source of the commercial feather supply is the poultry packing plant, since the number of chickens killed at home is so relatively few that the amount of feathers obtainable is very limited. Chicken manure produced at home is usually applied directly to the land while that collected in poultry packing plants is sometimes specially prepared as fertilizer. In packing plants dead birds and offal and blood-spoiled feathers are often added to the manure in the preparation of fertilizer. Chicken blood from packing houses is sometimes mixed with hog feed.

Feathers.—Although feathers are a by-product of the chicken industry, they have extensive uses, especially in the manufacture of millinery specialties and in the making of pillows, cushions, mattresses, dusters, artificial flowers and for other purposes. The various kinds of feathers, such as wing and tail, body, white, colored, dry plucked, scalded, clean and dirty, should be kept separate. Feathers are stored in large, well-ventilated rooms where they are stirred daily until thoroughly dried or they are dried by a specially constructed drying machine when the chickens are dry plucked, the feathers being collected from the floor or from boxes by means of suction pipes. Where the chickens are slack scalded, the feathers are run through a presser to press out much of the water and are then transformed to the drying machine.

White feathers are worth much more than colored feathers but all have a market value.

Manure.—Chicken manure is of considerable value as a fertilizer because it contains nitrogen, potash and phosphoric acid. Chicken manure is richer in plant food constituents than that of other farm animals. Van Slyke (1912) estimates that 100 hens averaging 5 lb. each in weight will produce in one year approximately 4,250 lb. of manure containing 43 lb. of nitrogen, 16 lb. of potash and 34 lb. of phosphoric acid.

Composition.—Haskins and Walker (1913) give the average plant food content of chicken manure as follows: nitrogen, 1.44 per cent; potash, 0.39 per cent; phosphoric acid, 0.99 per cent. Van Slyke gives the following composition: nitrogen, 1.01 per cent; potash, 0.37 per cent;

phosphoric acid, 0.80 per cent. After developing a method to collect urine from hens without contamination with feces, Davis (1927) conducted 14 trials with 5 hens to determine the nitrogenous constituents of the urine. It was found that the uric acid nitrogen averaged 62.9 per cent of the total urinary nitrogen. Ammonium nitrogen averaged 17.3 per cent, urea nitrogen 10.4, and the creatine plus creatinine 8 per cent of the total nitrogen. Since there probably is an unknown reabsorption of urea, creatine, and creatinine in the cloaca, it is not feasible to calculate urinary nitrogen from the uric acid in the droppings.

Storing.—When chicken manure is collected in considerable quantities it should be stored in a covered shed or box and is better if mixed with some absorbent material such as straw, peat or loam. Adding acid phosphate to the manure tends to reduce the loss of nitrogen because the acid phosphate combines with the ammonia as it is formed and produces non-volatile salt of ammonia. For this reason acid phosphate is a good substance to sprinkle on droppings boards.

Value.—The utilization of chicken manure for various crops has been discussed by Abbott (1924).

> Poultry manure, because of the high availability of its nitrogenous content, is peculiarly adapted to those crops which respond well to a liberal amount of quickly available nitrogen. It may be used in place of nitrate of soda around apple trees, or in place of either nitrate of soda or mixed goods for top dressing hay land, with certainty of good results. It is also suitable for general farm crops, market-garden crops, and, in short, may be used in lieu of other manures and fertilizers generally. Normally, single applications of poultry manure should not exceed two to three tons per acre, both because of danger of burning the crop or giving it an overration of nitrogen, and on account of probability of heavy loss by leaching.
>
> For those crops which can utilize liberal amounts of nitrogen, such as spinach, cabbage, mangels, corn, etc., and for other crops on very poor land, poultry manure may be applied at the rate of 40 lb. per square rod, or about 3 tons per acre. For crops which are more liable to injury by an overration of nitrogen, such as fruit trees, small fruits, potatoes, tomatoes, small grains and grass, and for all crops on rich land, it is safer to limit the application to 20 lb. per square rod.

Dead Birds and Offal.—Dead birds accumulating in poultry packing plants are utilized in making fertilizer and soap. The practice is increasing of "drawing" poultry in the more important areas of production before shipping the finished product to the more important centers of consumption. This means that larger quantities of offal are collected in the Middle West than formerly, with the result that practical means are being developed whereby the offal may be converted into fertilizer most economically. The same thing is being done at many of the poultry canning plants located in different parts of the country.

Eggshells, Infertile Eggs and Dead Embryos.—These are by-products of the commercial hatchery business and, taken in their aggregate for the country as a whole, amount to enormous proportions, inasmuch as there are probably more than 10,000 hatcheries in operation annually. Up to the present these by-products have been used as fertilizer and for hog-feeding purposes as well as in tanning. When properly prepared, however, they have good feeding value for poultry.

CHAPTER XXXI

THE ECONOMICS OF PRODUCTION AND MARKETING

The future development of the poultry industry in the United States depends upon certain economic principles which affect the development of all agricultural industries. The question of paramount importance in the mind of every poultryman and to those contemplating going into the poultry business is as to whether or not the poultry business is stable. It is interesting to note, in the meantime, that the poultry industry has increased relatively to a greater extent during recent years than many other agricultural enterprises.

It is well, therefore, for students of poultry husbandry to inquire concerning the position of the poultry industry in relation to other animal industries from the standpoint of the amount of human food produced from an acre of staple food products, as given in Tables 66 and 67.

Table 66.—Human Food from an Acre of Staple Farm Products (Henry and Morrison, 1923)[1]

	Yield per acre, pounds	Human food per acre	
		Digestible protein, pounds	Energy, therms
Dairy products:			
Milk	2,190	72.3	711.8
Cheese	219	56.7	427.0
Butter	99	1.0	355.3
Meat:			
Pork, 350 lb. live wt	273	22.7	672.9
Poultry 267 lb. live wt	171	33.0	178.7
Mutton, 205 lb. live wt	113	14.7	137.3
Beef, 216 lb. live wt	125	18.5	130.0
Eggs, 122.4 doz	184	24.6	132.2
Food crops:			
Corn, 35 bu	1,960	147.0	3,124.2
Irish potatoes, 100 bu	6,000	66.0	1,908.0
Wheat, 20 bu	1,200	110.4	1,788.0
Oats, 35 bu	784	89.4	1,254.4

Table 66 is from Henry and Morrison (1923) and shows that among the animal products the dairy products are the most efficiently produced.

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[1] Henry and Morrison, "Feeds and Feeding." By permission of The Henry Morrison Company, publishers.

Next to the dairy cow in acre returns of digestible protein and energy comes the hog, followed by poultry, beef cattle and sheep.

Spillman (1917, 1924) gives similar information in a more extensive form as shown in Table 67. Particular attention is drawn to the standing

TABLE 67.—RELATIVE PRODUCTION OF HUMAN FOOD PER ACRE FROM DIFFERENT ENTERPRISES

(Spillman, 1924)[1]

Enterprise	Per acre					Equivalent to acre of corn, days labor required			
	Unit used	Weight of unit, pounds	Yield	Edible protein, pounds	Thousands of calories	Acres	Man	Horse	Approximate farm value
Corn	Bu.	56	26.6	111.0	2,297	1.00	2.5(*a*)	6.0	17
Barley	Bu.	48	25.6	84.0	1,310	1.75	3.5	5.2	26
Winter wheat	Bu.	60	15.9	92.7	1,160	1.98	4.0	5.9	28
Oats	Bu.	32	30.0	92.8	1,071	2.15	4.3	6.5	25
Milk	Lb.	1	1,755.0	57.9	570	4.03	54.0	22.2	107
Cheese (*b*)	Lb.	1	175.5	45.5	342	6.72	90.0	37.0	142
Butter (*b*)	Lb.	1	79.0	0.8	285	8.06	108.0	44.3	153
Pork	Lb.	1	266.0(*c*)	17.2	512	4.49	16.2	22.9	84
Beef followed by	Lb.	1	121.45	12.5	147	15.60	51.8	87.0	171
Pigs	Lb.	1	40.48						
Poultry—meat	Lb.	1	81.20	229.0	126	18.20	35.7	58.2	466
Eggs	Doz.	1½	82.40						
Mutton (*d*)	Lb.	1	151.70	10.5	98	23.4	50.5	90.6	177

[1] SPILLMAN, W. J., "Farm Management." By permission of Orange, Judd Company, publishers.

a. Husked from standing stalks.

b. Labor in making butter and cheese not included; in case of all meat animals, labor of growing feed and caring for animals is included.

c. Live weight for all meat animals. *d.* Thirteen pounds of wool also.

TABLE 68.—MARKETABLE PRODUCT AND EDIBLE SOLIDS PRODUCED PER HUNDRED POUNDS OF DIGESTIBLE ORGANIC MATTER CONSUMED IN THE RATION

(Jordan, 1917)[1]

	Marketable product, pounds	Edible solids, pounds
Milk	139.0	18.0
Swine	25.0	15.6
Cheese	14.8	9.4
Butter	6.4	5.4
Eggs	19.6	5.1
Fowl, dressed carcass	15.6	4.2
Fowl, live weight	19.6	
Broilers, dressed carcass	23.8	3.5
Broilers, live weight	28.7	
Steers	8.3	2.8
Sheep and lambs	7.0	2.6

[1] JORDAN, W. H., "The Feeding of Animals." By permission of The Macmillan Company, publishers.

of poultry as compared with other enterprises in the approximate farm values given in the right-hand column of the table.

The number of pounds of marketable product and of edible solids per hundred pounds of digestible organic matter consumed in the ration by different animals are given in Table 68, from Jordan (1917).

From the three tables given above, it is observed that poultry raising ranks favorably as a branch of agriculture in supplying humans with food of animal origin. Furthermore, it should be pointed out that the chicken is the smallest economic unit of all the animals considered in this discussion, it reproduces relatively more rapidly and, therefore, can be developed to a higher state of efficiency in less time.

THE AMOUNT AND DISTRIBUTION OF CAPITAL INVESTED IN POULTRY FARMING

The amount of capital invested in poultry farming and its proper distribution among the various investments are vital factors affecting labor income. Those engaged in the business of poultry raising are vitally interested in this matter because it is desirable that they make the most efficient investments and in order that they may know to what extent it is best to expand in one direction and curtail in another. Persons contemplating going into the poultry business should have a thorough understanding of the amount of capital required and how best to

TABLE 69.—INDEX NUMBERS OF FARM PRICES FOR POULTRY, EGGS AND OTHER FARM PRODUCTS, 1910 TO 1926

(August 1909 to July 1914 = 100) Bur. Agr. Econ., U. S. Dept. Agr. (Johnson, 1927)

Year	Eggs	Chickens	Meat animals	Dairy products	Grains
1910	105	103	103	100	104
1911	90	94	87	97	96
1912	102	96	95	103	106
1913	100	104	108	100	92
1914	105	107	112	100	103
1915	102	104	104	98	120
1916	116	117	120	102	126
1917	159	147	173	125	217
1918	186	184	202	152	226
1919	206	210	206	173	231
1920	222	224	173	188	231
1921	155	182	108	148	112
1922	133	167	113	134	105
1923	140	165	106	148	114
1924	141	168	109	134	129
1925	157	178	139	137	156
1926	147	192	146	136	129

invest it among the various items necessary. The amount of capital is often the limiting factor.

Although it is necessary to discuss investments in terms of dollars and cents, it should be borne in mind that the prices of various commodities change from season to season and from year to year. Prices of all commodities are much higher now than 10 or 12 years ago, as shown in Table 69, although it is probably true that the distribution of the various investments in poultry raising are still in about the same ratio.

Table 70 gives the percentage of capital invested in the various items mentioned in the table on farms in New Jersey, New York State and Long Island.

TABLE 70.—DISTRIBUTION OF CAPITAL INVESTED ON FARMS DEVOTED TO POULTRY RAISING

	Per cent of total capital invested		
	New Jersey, 1918*	New York State, 1927†	Long Island, 1927‡
Real estate	76.9	73.3	86.6
Poultry	15.8	12.5	10.2
Other livestock		4.5	0.2
Machinery and equipment	4.3	8.7	2.8
Feed and supplies	1.5	1.0	0.2
Cash	1.5		
Total	100.0	100.0	100.0

* 150 commercial poultry farms (App, Waller and Lewis 1918).

† 121 farms in New York, excluding Long Island (Misner, Johnson and Marble, 1927).

‡ 32 specialized farms on Long Island (Misner, Johnson and Marble, 1927).

It is observed from Table 70 that the distribution of the investments in total capital in the three sections of the country are quite comparable. The fact is appreciated, of course, that real estate values are higher on Long Island than on the farming areas of the rest of New York and in New Jersey. It is undoubtedly true that in most other parts of the country the percentage of the total capital invested in real estate would be less than in New Jersey or on Long Island.

The distribution of the real estate capital on 32 Long Island and 121 other farms in New York State, not on Long Island, is shown in Table 71.

It is unfortunate that data on the distribution of real estate capital from other parts of the country are not available, but the fact can be appreciated that in all parts of the country the percentages of capital invested in dwellings and poultry buildings constitute the major items of investment, except where land other than that used for poultry is considered.

TABLE 71.—DISTRIBUTION OF REAL ESTATE CAPITAL ON FARMS IN NEW YORK STATE

(Misner, Johnson and Marble, 1927)

	Per cent of total capital	
	New York State	Long Island
Dwellings	31.3	27.7
Poultry buildings	22.8	17.6
Barns and other buildings	9.7	2.3
Yards and ranges	5.3	17.3
Other land	30.9	35.1
Total	100.0	100.0

Data on the distribution of capital invested exclusively in the poultry plant are available from California, the data having been supplied by Melvin Buster, formerly Extension Poultry Specialist of the University of California. The data for three counties in California are given in Table 72.

TABLE 72.—DISTRIBUTION OF CAPITAL INVESTED EXCLUSIVELY IN THE POULTRY PLANT IN VARIOUS COUNTIES IN CALIFORNIA

(Buster and Fluharty, 1926)

	Per cent of total capital, by counties		
	Placer	Humboldt	Kern
Poultry	44.4	39.5	37.4
Buildings and fences	43.8	30.6	27.0
Land	6.7	12.5	22.9
Feed	0.6	2.1	4.3
Equipment, etc	4.2	14.5	8.2
Supplies, etc	0.3	0.8	0.2
Total	100.0	100.0	100.0

It is observed that in all three counties in California the major items of investment are poultry and buildings and fences. The proportion of capital invested in land varies considerably among the three counties, as does also the invested capital in equipment. In the northern parts of the United States, where the winter weather is more severe than in California, it is probable that the proportion of capital invested in buildings and fences would be higher than in California. Where confinement rearing and keeping the layers in confinement are practiced, the proportion of capital invested in land would naturally be a minor item.

SOURCES OF INCOME AND ITEMS OF EXPENSE

It is well for poultrymen to know which phases of their poultry raising operations are economically the most important in order that due consideration may be given to making the entire poultry raising business as efficient as possible. Data showing the percentages of the total poultry and farm receipts obtained from the various items are given in Table 73, the information having been obtained from California and New York in 1926 and 1927.

Table 73.—Sources of Income on Farm and Commercial Poultry Plants in California and New York

Items	Per cent of total receipts							
	California, by counties						New York	
	Kern	Humboldt	Placer	Ventura	Sonoma	Tulare	Not on Long Island	Long Island
Eggs:								
Market	64.9	70.2	76.0	80.1	83.1	76.3	54.2	67.8
Hatching	3.9	3.8	0.7	.....	10.1	0.5	0.8	0.5
Consumed	3.0	0.9	2.4	0.6	2.0	1.6		
Poultry	21.4	22.7	10.2	7.9	4.2	16.0		
Baby chicks	.....	.....	.....	.....	.....	.....	8.1	4.9
Pullets	.....	.....	.....	.....	.....	.....	2.6	3.8
Market	.....	.....	.....	.....	.....	.....	9.4	17.6
Breeding	.....	.....	.....	.....	.....	.....	0.8	0.6
Consumed	1.8	0.2	0.7	0.1	.....	0.7		
Other livestock	.....	.....	.....	.....	.....	.....	2.3	
Milk products	.....	.....	.....	.....	.....	.....	5.3	
Crops	.....	.....	.....	.....	.....	.....	8.8	0.6
Increase in capital	4.8	0.8	8.9	8.0	.....	.....	4.8	2.3
Miscellaneous receipts	0.2	1.4	1.1	3.3	0.6	4.9	2.9	1.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

From the data given in Table 73 it is observed that market eggs constitute the chief source of all returns from farms and commercial poultry plants. It is probably true that in the data given for the various counties of California the percentage of total poultry receipts accredited to poultry should have been divided among the various items enumerated, but such information was not available.

Vickers and Cray (1925–1926) analyzed the receipts from 440 flocks in all parts of Ohio for 1924 and found that the following percentages of the total poultry receipts secured from the various items were: (1) Leghorns and similar breeds, eggs 82.4, hens 7.9, broilers 8.2, breeders

1.5; (2) Plymouth Rocks and similar breeds, eggs 68.8, hens 17.8, broilers 12.3, breeders 1.1.

It is clear, therefore, that high egg production per bird is one of the most important factors affecting receipts from the poultry flock.

The items of expense in the operation of a commercial poultry plant and of a farm flock are available from the California and New York plants as given in Table 74.

Table 74.—Items of Expense in the Operation of a Commercial and Farm Poultry Plant

Item	Per cent of total expenses							
	California, by counties						New York	
	Kern	Humboldt	Placer	Ventura	Sonoma	Tulare	Not on Long Island	Long Island
Feed	60.1	59.0	60.7	56.5	53.8	55.0	54.4	68.6
Labor:								
Unpaid	19.9	18.1	15.5	16.8	15.4	14.0	12.9	7.9
Hired	0.4	2.0	0.2	4.7	3.7	6.1	7.1	7.4
Interest	6.9	5.4	5.0	6.1	7.1	7.2		
Poultry bought	8.1	8.5	8.9	7.9	17.3	5.8		
Water, taxes, etc	0.5	1.4	1.5	2.0	1.5	2.8	3.2	2.6
Miscellaneous	1.9	3.0	5.2	3.7	1.2	3.2	22.4	13.5
Depreciation	2.2	2.6	3.0	2.3	.....	5.9		
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

From the data given in Table 74 it is obvious that feed and labor constitute the chief items of expense in the operation of farm and commercial poultry plants. The data given for the New York State farms and poultry plants are not quite comparable with those given for the California poultry plants in so far as the items of Interest, Poultry Bought, Miscellaneous and Depreciation are concerned for the simple reason that these items were not given in the New York State returns and all items for the New York State farms except those for which values are given in Table 74 are classed under the item Miscellaneous. The important thing to be kept in mind, however, is that feed and labor constitute the chief items of expense.

Johnson and Frame (1924) present the following data regarding the items of expense in operating farm poultry plants in Missouri, based on records kept on 115 farms from 1912 to 1922: Feed, 56.3 per cent of the total costs; man labor, 27.7; horse labor, 0.9; cash expenses, 7.5;

buildings and equipment, 4.0; taxes and interest, 3.6. Here, again, the cost of feed is shown to be the most important item of expense with labor second.

In a survey of 23 farms in Medina County, Ohio, covering the five-year period ended December 31, 1924, Morison (1928) states that "feed constituted 57.8 per cent of the cost of the poultry enterprise, labor 24.2 per cent, and other items 18.0 per cent." Incidentally, it is interesting to note that Morison observes: "Poultry was second in importance among the live-stock enterprises on these farms, yielding 10.5 per cent of the total farm receipts."

The distribution of the various factors of cost in producing eggs on New York farms is shown in Table 75.

TABLE 75.—DISTRIBUTION OF COST FACTORS IN PRODUCING EGGS IN NEW YORK STATE
(Misner, Johnson and Marble, 1927)

Cost factors	Per cent of total costs	
	Not on Long Island	Long Island
Feed	46.2	44.5
Labor:		
Human	19.8	22.5
Horse	0.6	0.1
Depreciation in flock	18.2	17.6
Use of buildings	6.6	5.0
Interest	2.0	1.8
Litter	1.3	1.5
Use of auto	1.1	1.7
Use of equipment	0.5	1.5
Use of yards and range	0.5	0.3
Miscellaneous	3.2	3.5
Total	100.0	100.0

The data in Table 75 show that feed, labor and depreciation in the flock are the three most important cost factors in producing eggs, the three items accounting for approximately 85 per cent of the total costs of producing eggs.

INCUBATION COSTS

The factors of cost in incubating eggs include the value of the eggs incubated, labor, fuel, the use of the incubators and other miscellaneous items. Misner, Johnson and Marble (1927) give the distribution of incubation costs for 19 farms on Long Island and 77 farms in New York State not on Long Island, as shown in Table 76. The Long Island farmers secured a 58.0 per cent hatch and the other farmers a 57.2 per cent hatch.

Table 76.—Distribution of Costs in Incubation in New York State (Misner, Johnson and Marble, 1927)

Cost items	Per cent of total cost	
	19 farms on Long Island	77 farms not on Long Island
Eggs	74.4	68.7
Labor	8.0	12.5
Miscellaneous	17.6	18.8
Total	100.0	100.0

The cost of incubation per chick hatched is affected greatly by the hatching percentage secured. The importance of this point is well illustrated in Table 77, which gives the egg cost per chick for eight hatcheries in the state of Washington. The higher the hatching percentage the lower the egg cost per chick.

Table 77.—Egg Cost per Chick in Relation to Hatching Percentage (Carver and Buchanan, 1926)

Hatchery number	Eggs set	Chicks hatched	Per cent hatch	Egg cost per chick, cents
1	49,117	25,365	52.0	8.1
2	273,200	154,950	57.0	7.4
3	115,200	68,000	59.0	7.1
4	378,000	223,000	60.0	6.8
5	40,318	25,100	62.0	6.7
6	16,000	10,000	62.5	6.7
7	24,500	18,000	73.0	5.7
8	29,000	22,000	76.0	5.5

Lowrie (1929) presents interesting information regarding the average operating expenses and revenues of 19 accredited hatcheries in Ohio for 1927. Although it is true that prices of eggs, chicks and other items vary in different parts of the country from year to year, nevertheless, it is true that any statement showing the relative distribution of the expenses and revenues in the hatchery business for any year should be of great interest and value to all hatchery operators and others for all other years. With this in mind there are given in the next three tables information obtained by Lowrie in her analysis of the results secured by the Ohio accredited hatcheries in 1927.

TABLE 78.—STATEMENT OF REVENUES AND EXPENSES PER $100 OF INCOME IN 19 OHIO ACCREDITED HATCHERIES, 1927

(Lowrie, 1929)

Sales:			
Baby chicks		$96.39	
Custom hatching		3.61	
Total			$100.00
Cost of sales:			
Direct cost:			
Egg cost	$35.50		
Labor	13.35	$48.85	
Indirect cost:			
Heat, light, power and water	$ 1.17		
Repairs, fixt. and equip	0.72		
Supplies and sundry hatch. exp	0.66		
Taxes, personal property	0.36		
Insurance, fixt. and equip	0.66		
Depreciation, fixt. and equip	5.32		
Rent or equiv. bldg. expense	1.18	10.07	
Chick purchases		6.60	65.52
Gross margin			$ 34.48
Expenses, selling and administrative:			
Advertising		$ 5.95	
Telephone and telegraph		0.39	
Boxes and twine		1.26	
Postage and express		2.30	
Automobile expense		0.71	
Office supplies and expense		0.65	
Replacements		0.62	
Accrediting expense		0.91	
Bad debts		0.54	13.33
Net profit from hatchery			$ 21.15

Hatchery operators may find an advantage in thinking of this table in the following terms: In the average hatchery, out of each $100 of revenue, $3.61 was earned through custom hatching work while $96.39 came from the sale of baby chicks. The cost of eggs for the chicks produced for this $100 of sales was $35.50, while the entire labor cost for the hatchery amounted to $13.35 for each $100 of revenue.

Occupancy expenses, including rent, heat and light, repairs, depreciation, insurance, etc., consumed $10.07 out of each $100 of revenue. The purchase of baby chicks from other hatcheries to supply the demands of customers not met by the production from owned incubators averaged $6.60 for each $100 of sales.

These direct expenses, or cost of the sales, totaled $65.52 for each $100 sale, leaving $34.48 to cover selling and administrative expenses and profit. The group average showed that it cost $13.33 in selling and administrative expenses to make each $100 of revenue and left $21.15 as operating profit on the sales.

Advertising expenditures of the average hatchery amounted to $5.95 for each $100 of sales. Delivery costs were $1.26 for boxes and twine and $2.30 for postage and express, a total of $3.56 for each $100 of sales. Replacements cost 62 cts. on each $100 of sales, while bad debts averaged 54 cts. for each $100 of sales.

The distribution of the average expenses in producing and selling 100 chicks in the Ohio accredited hatcheries is shown in Table 79.

TABLE 79.—STATEMENT OF AVERAGE EXPENSES PER 100 CHICKS IN 18 OHIO ACCREDITED HATCHERIES, 1927
(Lowrie, 1929)

Direct costs:		
Egg cost	$4.60	
Labor	1.79	$6.39
Indirect cost:		
Heat, light, power and water	$0.11	
Repairs, fixt. and equip	0.04	
Supplies and sundry hatch. exp	0.03	
Taxes, personal property	0.07	
Insurance, fixt. and equip	0.09	
Depreciation, fixt. and equip	0.66	
Rent or equiv. bldg. expense	0.14	1.14
Total production costs		$7.53
Expenses, selling and administrative:		
Advertising	$0.51	
Telephone and telegraph	0.05	
Boxes and twine	0.17	
Postage and express	0.25	
Automobile expense	0.04	
Office supplies and expense	0.03	
Replacements	0.01	
Accrediting expense	0.10	1.16
Total costs per 100 chicks		$8.69

The data in Table 79 show that the egg cost amounts to $4.60 out of a total cost of $8.69 per 100 chicks. Labor is the next most important cost factor. Among the selling and administrative items of cost, advertising and postage and express are the two most important items.

The commercial hatchery season extends for the most part from February to June, inclusive. It is well known that the price of eggs is higher in February than during the rest of the hatchery season and since the cost of eggs represents $35.50 out of a total of $78.85 producing, selling and administrative costs per $100 of income (Table 78) and since the cost of eggs represents $4.60 out of a total cost of $8.69 in producing 100 chicks (Table 79), it is interesting to determine the margin between egg cost and sales price per chick for each hatch as the hatching season progresses.

The data in Table 80 show that in the case of the Ohio accredited hatcheries in 1927 the margin between egg cost and sales price per chick was greatest from Mar. 13 to May 8 inclusive.

Table 80.—Weekly Averages of Egg Costs, Selling Price and Margin between Egg Cost and Sales Price per Chick in Ohio Accredited Hatcheries, 1927 (Lowrie, 1929)

Week beginning		Egg price per egg set, cents	Egg cost per chick hatched, cents	Sales price per chick, cents	Margin between egg cost and sales price per chick, cents
Feb.	13	4.6	8.5	13.2	4.7
	20	4.1	8.1	13.6	5.5
	27	3.8	7.1	11.6	4.5
Mar.	6	3.7	6.3	12.9	6.6
	13	3.4	5.6	13.6	8.0
	20	2.8	4.7	11.9	7.2
	27	2.8	4.6	12.4	7.8
Apr.	3	2.8	4.3	12.5	8.2
	10	2.8	3.7	11.8	8.1
	17	2.4	3.5	10.9	7.4
	24	2.3	3.4	10.6	7.2
May	1	2.3	3.4	10.7	7.3
	8	2.3	3.5	9.7	6.2
	15	2.8	4.2	9.9	5.7
	22	2.8	4.3	9.7	5.4
	29	2.7	4.2	9.6	5.4
June	5	2.7	4.0	8.6	4.6
	12	2.5	3.9	8.6	4.7
	19	2.3	3.5	7.7	4.2

BROODING COSTS

The cost of brooding chicks is an important problem that has received very little attention. Apparently no records have been kept or are available concerning all cost factors such as investment in the brooder house, labor and overhead expenses in addition to the actual fuel costs. A few records are available relating to the amount and cost of fuel consumed during the brooding period.

Smyth (1923) reports that 1,000 lb. of anthracite coal are required to run one stove brooder 10 weeks. Hannas (1924), with 19 coal-stove brooders, each brooding from 250 to 300 chicks, found that the amount of coal burned per stove daily was 16.9 lb. The fuel cost per chick of the Plymouth Rock and similar breeds was 3½ cts. up to 8 weeks of age, after which no more heat was necessary. For chicks of the Leghorn and similar breeds the fuel cost per chick was 1⅒ cts. up to 6 weeks of age, after which no more heat was used.

Dougherty (1923) conducted a survey of brooding costs in California and, with coal valued at $26 per ton, coal oil at 15 cts. per gallon, gas at 90 cts. per cubic foot and electricity at 4 cts. per kilowatt-hour, reported fuel costs of brooding chicks in lots of 250 chicks up to 50 days. Brooding with the use of electricity cost $3.14; with use of coal oil, $3.44; with the use of coal, $3.55; with the use of gas (in hot-water pipe systems), $1.94. It should be borne in mind that the cost of coal is much higher in California than in most parts of the country.

Moses and Wood (1927) report that in electric brooding with electricity at 2 cts. per kilowatt-hour, when radiation is depended upon as the method of heat transfer, the heating cost averages about 2.5 to 3 cts. per chick each 1,000 hr., and in brooders depending upon convection the heating cost averages about ¾ to 1 ct. per chick.

REARING COSTS

There are a number of factors that make up the total cost of rearing chickens, the two most important being feed and labor. Misner, Johnson and Marble (1927) give the distribution of the various items of expense in raising pullets on 31 farms on Long Island and on 117 farms in New York State not on Long Island. The data are given in Table 81.

TABLE 81.—DISTRIBUTION OF COSTS IN RAISING PULLETS IN NEW YORK STATE (Misner, Johnson and Marble, 1927)

Items	Per cent of total costs	
	31 farms on Long Island	117 farms not on Long Island
Feed	60.1	64.3
Labor:		
Human	18.5	17.4
Horse	0.0	0.5
Use of buildings	4.2	6.5
Use of yards and range	8.6	2.8
Use of equipment	1.3	1.7
Use of auto	0.3	0.4
Litter	0.8	0.7
Interest	1.7	1.8
Miscellaneous	4.5	3.9
Total	100.0	100.0

Feed is the most important single factor in the raising of chickens, with labor as the second.

FEED COSTS IN POULTRY RAISING

It has been shown in Tables 74 and 81 and in the preceding discussion that feed costs represent well over one-half of the total costs of poultry production. It is interesting to determine therefore, the amount of feed consumed by growing chickens, laying hens and fattening birds.

Feed Consumption by Growing Chickens.—The following tables and discussion give information regarding the approximate amounts of feed consumed by chicks at different ages, the approximate amounts of feed required to produce chicks of different weights and the approximate amounts of feed required to develop a pullet to laying age and a cockerel to roaster size.

Philips (1918) has reported the results of determinations made concerning the quantity of grain feed required to raise White Plymouth Rock chicks to maturity. It was found that it took approximately 30 lb. of grain feed per bird to raise pullets up to and including 28 weeks of age

Table 82.—The Average Weight per Chick per Week and the Average Quantity of Grain Feed Consumed per Chick per Week in White Leghorns and Rhode Island Reds

(Card and Kirkpatrick, 1918)

Week	White Leghorns		Rhode Island Reds	
	Average weight per chick, pounds	Average quantity of grain feed consumed per chick, pounds	Average weight per chick, pounds	Average quantity of grain feed consumed per chick, pounds
0	0.08	0.00	0.08	0.00
1	0.11	0.07	0.11	0.08
2	0.18	0.15	0.16	0.16
3	0.26	0.25	0.26	0.24
4	0.38	0.32	0.36	0.33
5	0.50	0.41	0.54	0.44
6	0.69	0.51	0.74	0.60
7	0.90	0.66	0.96	0.69
8	1.09	0.74	1.23	0.88
9	1.22	0.84	1.52	0.94
10	1.41	0.93	1.80	1.01
11	1.56	0.98	2.01	1.07
12	1.80	1.00	2.30	1.19
13	1.93	1.07	2.39	1.16
14	2.06	1.04	2.51	1.15
15	2.21	1.12	2.76	1.23
16	2.36	1.12	2.91	1.39
17	2.49	1.33	3.14	1.54
18	2.63	1.30	3.22	1.60
19	2.72	1.37	3.44	1.52
20	2.90	1.43	3.68	1.69
21	3.05	1.39	3.85	1.70
22	3.12	1.36	4.03	1.73
23	3.23	1.33	4.16	1.67
24	3.28	1.41	4.30	1.76
Total		22.13		25.77

and approximately 33 lb. of grain feed to raise cockerels up to and including 28 weeks of age.

Card and Kirkpatrick (1918) determined the quantity of feed consumed per chick weekly for 24 consecutive weeks by White Leghorns and Rhode Island Reds. The results are shown in Table 82.

Judging from the results secured by Philips and Card and Kirkpatrick, it may be safely assumed that the quantity of grain feed required to raise White Leghorns to maturity is about 20 to 25 lb., and to raise White Plymouth Rocks, Rhode Island Reds, and chickens of other general-purpose breeds to maturity is about 25 to 35 lb.

Brightman and Margolf (1925) found that in the case of 1,797 chicks, the amount of feed consumed during the first 6 weeks averaged 1.14 lb. of mash, 0.37 lb. of scratch grain and 3.64 lb. of milk per bird. Charles and Knandel (1928) give data (Table 83) showing the weekly weights and feed consumption of Barred Plymouth Rock chickens grown in confinement. The same information is given in Table 84 for White Leghorn chickens reared under similar conditions.

TABLE 83.—FEED CONSUMPTION, MORTALITY AND WEIGHT OF BARRED PLYMOUTH ROCK CHICKS GROWN IN CONFINEMENT
(Charles and Knandel, 1928)

Weeks	Weekly feed consumption per 100 chicks			Per cent mortality	Pullets, average weight pounds	Cockerels, average weight pounds
	Grain, pounds	Mash, pounds	Total, pounds			
1	0.63	25.53	26.16	0.84	0.117	0.117
2	5.08	15.25	20.33	0.00	0.179	0.179
3	7.63	17.37	25.00	0.00	0.305	0.305
4	11.87	29.66	41.53	0.00	0.408	0.451
5	15.68	34.32	50.00	0.00	0.578	0.603
6	18.86	36.86	55.72	0.00	0.733	0.771
7	37.50	47.03	84.53	0.42	0.955	1.03
8	23.60	34.55	58.15	0.00	1.15	1.26
9	37.92	51.28	89.20	0.42	1.38	1.57
10*	34.89	57.02	91.91	0.00	1.62	1.87
11	49.79	31.49	81.28	1.70	1.92	
12	56.05	58.87	114.92	0.00	2.13	
13	62.50	48.79	111.29	0.00	2.38	
14	63.71	43.15	106.86	0.00	2.63	
15	59.68	66.13	125.81	0.00	2.89	
16	87.10	59.27	146.37	0.00	3.13	
17	78.23	45.60	123.83	0.00	3.35	
18	84.68	62.90	147.58	0.00	3.54	
19	65.32	60.08	125.40	0.00	3.73	
Total	800.72	825.15	1,625.87	3.38		

* Cockerels removed at end of tenth week.

Table 84.—Feed Consumption, Mortality, and Weight of Single Comb White Leghorn Chicks Grown in Confinement

(Charles and Knandel, 1928)

Weeks	Weekly feed consumption per 100 chicks			Per cent mortality	Average weight per chick, pounds
	Grain, pounds	Mash, pounds	Total, pounds		
1	1.11	13.99	15.10	1.60	0.117
2	4.99	22.30	27.29	1.96	0.190
3	8.28	24.10	32.38	0.61	0.303
4	11.78	27.49	39.27	0.54	0.444
5	16.24	35.25	51.49	0.13	0.565
6*	21.38	37.47	58.85	0.41	0.787
7	28.16	41.46	69.62	0.08	0.898
8	30.11	47.41	77.52	0.32	1.104
9	32.27	46.18	78.45	0.25	1.202
10	38.00	52.40	90.40	0.11	1.38
11	43.26	46.39	89.65	0.12	1.58
12	49.59	39.10	88.69	0.00	1.69
13	48.47	46.07	94.54	0.11	1.87
14	48.41	46.83	95.24	0.23	2.07
15	53.75	41.66	95.41	0.15	2.42
16	57.93	50.26	108.19	0.00	2.31
17	60.97	42.88	103.85	0.18	2.75
18	67.33	53.01	120.34	0.25	2.82
19	63.75	62.50	126.25	0.00	3.02
Total	685.78	776.75	1,462.53	7.05	

* Cockerels removed at the end of sixth week.

Jull and Titus (1928) present data regarding the amount of feed consumed per two-week period in relation to the average weight per chick in the case of females and males raised separately. The data are given in Table 85. It should be pointed out that 453.60 g. equal 1 lb. It should also be pointed out that the chicks were the progeny of Barred Plymouth females mated to Rhode Island Red males, a cross which enables the separation of sexes at hatching time.

From the results given in Table 85 it is apparent that males grow faster than females but that both sexes may attain a weight approximating 2 lb. per bird at from 10 to 12 weeks of age, at which age the feed consumption amounts approximately from 5 to 9 lb., females consuming less than males. It is also interesting to note that at 24 weeks of age the pullets attained approximately 4¾ lb. each on a feed consumption of approximately 25 lb. per bird, whereas at 24 weeks of age the cockerels attained approximately 6½ lb. each in weight on a feed consumption of approximately 30 lb. per bird.

TABLE 85.—RELATION BETWEEN FEED CONSUMPTION AND LIVE WEIGHT OF CHICKENS IN LOTS 1 TO 4
(Jull and Titus, 1928)

Age, weeks	Number of birds	Average feed consumption		Average weight per bird, grams
		Per period, grams	Total, grams	
		Lot 1, Females		
0	33	....	....	34.5
2	32	127.14	127.1	90.8
4	32	271.16	398.3	215.3
6	32	511.28	909.6	387.3
8	32	688.19	1,597.8	618.1
10	32	846.94	2,444.7	835.9
12	31	1,176.41	3,621.1	985.5
14	31	1,256.89	4,878.0	1,334.6
16	31	1,251.04	6,129.1	1,541.3
18	31	1,316.88	7,445.9	1,651.8
20	31	1,534.90	8.980.8	1,860.2
22	31	1,559.77	10,540.6	2,026.9
24	31	1,613.18	12,153.8	2,211.5
		Lot 2, Females		
0	41	....	....	34.2
2	41	132.76	132.8	79.8
4	41	246.16	378.9	198.1
6	41	472.40	851.3	355.8
8	41	677.62	1,528.9	582.7
10	41	824.76	2,353.7	770.9
12	41	1,045.48	3,399.2	937.0
14	41	1,080.88	4,480.1	1,236.6
16	41	1,063.18	5,543.2	1.480.4
18	41	1,231.34	6,774.6	1,574.2
20	41	1,205.89	7,980.5	1,785.4
22	41	1,416.09	9.396.6	2.012.1
24	41	1,261.21	10,657.8	2,171.0
		Lot 3, Males		
0	43	....	....	35.0
2	43	111.82	111.8	77.1
4	43	236.29	348.1	185.4
6	43	489.99	838.1	366.8
8	41	788.26	1,626.3	608.1
10	41	863.49	2,489.8	773.2
12	40	1,219.03	3,708.9	1,091.1
14	40	1,322.22	5,031.1	1,505.9
16	39	1,284.02	6,315.1	1,773.0
18	39	1,639.91	7,955.0	2,046.0
20	39	1,520.70	9,475.7	2,386.8
22	39	1,721.33	11,197.0	2,736.4
24	39	1,625.37	12,822.4	2,906.3
		Lot 4, Males		
0	40	....	....	34.8
2	40	136.08	136.1	82.3
4	39	257.39	393.5	255.6
6	39	536.40	929.9	399.4
8	39	814.14	1,744.0	656.6
10	39	1,116.54	2,860.5	924.2
12	38	1,287.96	4,148.5	1,225.7
14	38	1,406.14	5,554.6	1,629.7
16	38	1,309.45	6,864.1	1,933.0
18	38	1,647.26	8,511.3	2,157.4
20	38	1,715.89	10,227.2	2,435.5
22	37	1,745.11	11,972.3	2,744.9
24	37	1,764.11	13,736.5	2,926.9

The Feed Cost of Egg Production.—The cost of producing eggs is affected by many factors which vary in different sections and which change from year to year, the three most important being feed, labor, and the average number of eggs laid per bird. Feed is the most important item, since it normally represents from one-half to two-thirds of the total cost of production.

Data concerning the quantity of feed consumed by laying hens have been obtained by a few of the state experiment stations. The quantity of feed consumed by laying hens is affected by a variety of factors, chief of which include the kind of food supplied, the size of the hens, and, to a certain extent, the number of eggs laid. A ration consisting of a variety of grains usually induces greater consumption than where only one grain is fed. Leghorns and similar breeds, which are smaller than the general-purpose breeds—Plymouth Rocks, Rhode Island Reds, Wyandottes and Orpingtons—consume less feed a year than birds of the larger breeds. Usually birds bred for high egg production consume slightly more feed than less well-bred birds of the same size. From data submitted by a number of experiment stations it is found that Leghorns laying an average of approximately 150 eggs per bird consume about 70 to 85 lb. of grain food per year and that general-purpose breeds with the same production consume about 80 to 95 lb. per year.

Philips (1921*b*) found that 70.29 lb. of feed per bird were consumed by Leghorn pullets averaging 136 eggs each in one year, 79.49 lb. of feed per bird by Leghorn pullets averaging 166 eggs each in one year and 84.67 lb. of feed per bird by Leghorn pullets averaging 193 eggs each in one year.

Misner, Johnson and Marble (1927) give the amounts of various feeds consumed per bird on 32 Long Island and 121 other New York State farms, as shown in Table 86.

TABLE 86.—AVERAGE AMOUNTS OF VARIOUS FEEDS CONSUMED PER BIRD ON NEW YORK STATE FARMS

(Misner, Johnson and Marble, 1927)

Feed items	Pounds of feed per bird	
	32 farms on Long Island	121 farms not on Long Island
Scratch grain	44.73	43.00
Mash	35.43	32.95
Green feed	5.32	3.75
Milk	3.93	2.54
Oyster shell	2.19	1.94
Cod-liver oil	0.27	0.10
Miscellaneous	0.86	0.63
Total	92.73	84.91

Kempster (1924) gives results secured in feeding tests conducted from 1914 to 1923 inclusive, the tests being conducted with White Leghorns to determine the relative value of various protein supplements. The summary of results is given in Table 87, the basis of comparison being the average number of pounds of feed required to produce one pound and one dozen eggs, respectively.

TABLE 87.—AVERAGE NUMBER OF POUNDS OF FEED REQUIRED TO PRODUCE ONE POUND AND ONE DOZEN EGGS, RESPECTIVELY, VARIOUS PROTEIN SUPPLEMENTS HAVING BEEN USED

(Kempster, 1924)

Kind of protein supplement used	No. of tests	Average pounds feed consumed			Average number eggs laid	Pounds feed to produce in eggs	
		Scratch	Mash	Total		1 lb.	1 doz.
Sour milk	6	49.0	24.0	73.0	125	4.7*	7.0*
Meat scraps	5	50.0	26.6	76.6	117	5.2	7.8
Tankage	4	51.0	30.0	80.0	120	5.4	8.0
Dried buttermilk	2	43.5	33.5	77.0	112	5.5	8.2
No supplement	6	49.0	21.0	70.0	61	9.3	13.8

* Does not include milk.

It is obvious from the results given in Table 87 that the amount of feed consumed and the number of eggs produced per bird are of the greatest importance in determining the efficiency of a ration. The laying hen consumes part of her ration for maintenance purposes and the balance for egg production. Naturally, the more eggs she lays the more feed she requires up to a certain limit.

The relationship between egg production and the amount of feed consumed per bird is well illustrated in data secured by Allen (1923, 1924, 1925, 1926, 1927) and Black (1928, 1929). Records of egg production and feed consumption were obtained from poultry farms in New Jersey for the years 1923 to 1928 inclusive. Each year there were over 20,000 birds, almost all White Leghorns, on the farms from which the records were obtained. The data have been compiled in Table 88, which also gives for each year the number of pounds of feed required to produce one dozen eggs.

It is well known that egg production varies considerably from season to season and that heavy-laying hens consume more feed than poor layers. It is interesting, therefore, to determine the number of pounds of feed required to produce one dozen eggs each month of the year. Data covering this point have been accumulated by Jull (1923*b*) for Barred Plymouth Rocks and Rhode Island Reds and are given in Table 89.

TABLE 88.—NUMBER OF POUNDS OF FEED REQUIRED TO PRODUCE ONE DOZEN EGGS ON NEW JERSEY WHITE LEGHORN FARMS, 1923 TO 1928, INCLUSIVE

(Allen and Black)

Year	Feed consumed per bird			Eggs laid per bird	Pounds feed to produce 1 doz. eggs
	Scratch	Mash	Total		
1923	41.5	35.2	76.7	142.1	6.5
1924	43.3	32.2	75.5	142.6	6.3
1925	44.4	30.3	74.7	140.6	6.4
1926	45.7	28.5	74.2	144.0	6.2
1927	45.6	28.6	74.2	155.5	5.7
1928	46.3	29.8	76.1	163.2	5.6
1929	45.1	32.5	77.6	149.9	6.2

TABLE 89.—NUMBER OF POUNDS OF FEED REQUIRED TO PRODUCE ONE DOZEN EGGS EACH MONTH OF THE YEAR IN BARRED PLYMOUTH ROCKS AND RHODE ISLAND REDS

(Jull, 1923*b*)

Month	Barred Plymouth Rocks			Rhode Island Reds		
	Pounds of feed per bird	Eggs laid per bird	Pounds of feed to produce 1 doz. eggs	Pounds of feed per bird	Eggs laid per bird	Pounds of feed to produce 1 doz. eggs
Nov.	7.73	8.19	11.3	7.38	6.70	13.2
Dec.	8.48	9.15	11.1	7.86	9.82	9.6
Jan.	8.28	11.29	8.8	7.95	13.00	7.3
Feb.	8.38	13.91	7.2	7.92	15.47	6.1
Mar.	8.35	14.52	6.9	8.20	15.67	6.3
Apr.	8.37	14.72	6.8	7.96	15.21	6.3
May	7.91	13.24	6.2	7.24	14.32	6.1
June	7.91	11.88	8.0	7.27	12.58	6.9
July	7.65	10.20	9.0	7.16	10.77	8.0
Aug.	7.70	9.28	10.0	7.02	10.99	7.7
Sept.	7.65	7.28	12.6	7.21	8.58	10.1
Oct.	7.72	6.86	13.5	7.54	8.42	10.7
Total	96.13	130.52	8.8	90.71	141.53	7.7

The data in Table 89 show that feed consumption is slightly heavier during the months of greatest egg production than during the other months, but egg production is the vital factor in determining the number of pounds of feed required to produce one dozen eggs.

The effect of high production per month and for the year in determining the number of pounds of feed required to produce one dozen eggs is shown in Table 90, the records being for White Leghorns, data of Allen (1923).

TABLE 90.—NUMBER OF POUNDS OF FEED REQUIRED TO PRODUCE ONE DOZEN EGGS AS DETERMINED BY DIFFERENCES IN RATE OF EGG PRODUCTION IN WHITE LEGHORNS

(Allen, 1923)

Month	Annual average 142.1 eggs per bird			Annual average 197.8 eggs per bird		
	Pounds of feed per bird	Eggs laid per bird	Pounds of feed to produce 1 doz. eggs	Pounds of feed per bird	Eggs laid per bird	Pounds of feed to produce 1 doz. eggs
Nov.	5.7	4.7	14.5	6.8	19.8	4.1
Dec.	6.3	7.7	9.8	7.3	18.6	4.7
Jan.	6.8	9.1	9.0	7.2	15.5	5.6
Feb.	6.2	11.2	6.6	6.5	15.1	5.2
Mar.	6.7	15.4	6.2	7.0	18.7	4.5
Apr.	6.9	16.3	6.1	6.8	16.3	5.0
May	6.6	17.1	4.6	6.7	18.8	4.3
June	6.5	15.4	5.1	5.4	17.5	3.7
July	6.7	15.0	6.4	6.1	16.3	4.5
Aug.	6.6	14.3	5.5	6.2	13.0	5.7
Sept.	5.8	10.6	6.6	6.1	14.1	5.2
Oct.	5.9	5.3	13.4	6.2	14.1	5.3
Total	76.7	142.1	6.5	78.3	197.8	4.7

The data in Table 90 show that a difference in production of 55.7 eggs per bird was accounted for by a difference in feed consumption of only 1.6 lb. of feed per bird. Such a striking difference demonstrates the relative value of well-bred stock, 4.7 lb. as compared with 6.5 lb. of feed being required, respectively, to produce one dozen eggs for the year as a whole in each of the two groups of birds.

LABOR COSTS IN POULTRY FARMING

It has already been shown that in the raising of chickens and in egg production the amount of labor required is the second most important cost factor. Two kinds of labor are involved, man labor and horse labor. On commercial poultry plants practically the entire time of the operator is consumed in labor expended on the flock. On the general farm, however, the amount of labor expended on the poultry flock is determined very largely by the size of the flock and by the general interest the farmer or other members of the family have in the flock.

In the case of Missouri farm flocks varying in size from 20 to over 800 layers, Johnson and Frame (1924) found that the amount of man labor was 1.71 hr. per hen per year, distributed by months and varying somewhat for different years, as shown in Table 91.

TABLE 91.—MAN LABOR REQUIREMENTS IN POULTRY FARMING IN MISSOURI
(Johnson and Frame, 1924)

Month	Hours per hen	Year	Hours per hen
January	0.150	1912	2.10
February	0.140	1913	1.66
March	0.169	1914	1.98
April	0.212	1915	1.51
May	0.179	1916	2.03
June	0.144	1917	1.76
July	0.112	1918	1.71
August	0.109	1919	1.26
September	0.107	1920	2.44
October	0.103	1921	1.66
November	0.143	1922	1.54
December	0.142		
Total	1.710	Average	1.71

The horse labor requirements in caring for the poultry on Missouri farms are shown in Table 92.

TABLE 92.—HORSE LABOR REQUIREMENTS IN POULTRY FARMING IN MISSOURI
(Johnson and Frame, 1924)

Month	Hours per hen	Year	Hours per hen
January	0.0139	1912	0.0980
February	0.0110	1913	0.2409
March	0.0122	1914	0.1884
April	0.0106	1915	0.1207
May	0.0058	1916	0.1417
June	0.0036	1917	0.0854
July	0.0047	1918	0.0922
August	0.0047	1919	0.0092
September	0.0061	1920	0.0651
October	0.0089	1921	0.0806
November	0.0093	1922	0.0894
December	0.0193		
Total	0.1101	Average	0.1101

Misner, Johnson and Marble (1927) found that in the case of poultry farming on Long Island the average number of hours of human labor was 2.12 per hen and on other New York State farms it was 1.98 per hen per year. The same authors found that the amount of horse labor required was 0.03 hr. per hen or 3 hr. per 100 hens on the Long Island farms and on other New York State farms it was 0.16 hr. per hen or 16 hr. per 100 hens per year.

The size of the flock has a direct bearing on the average labor cost per bird, as shown in Table 93.

TABLE 93.—RELATION BETWEEN SIZE OF FLOCK AND LABOR COST PER BIRD IN THE STATE OF WASHINGTON

(Severance, 1927)

Groups	Number	Average number birds	Average total cost per flock	Average cost per bird
Oct. 1, 1923, to Oct. 1, 1924				
0 to 500 birds	6	407	$ 552	$1.36
501 to 1,000 birds	10	755	966	1.30
1,001 to 2,000 birds	7	1,410	1,552	1.10
All flocks	23	864	1,036	1.20
Oct. 1, 1924, to Oct. 1, 1925				
0 to 500 birds	4	442	$ 872	$1.97
501 to 1,000 birds	19	794	973	1.23
1,001 to 2,000 birds	14	1,398	1,575	1.12
2,001 and over	2	2,675	2,393	0.90
All flocks	39	1,071	1,252	1.17

The data in Table 93 show that flocks of about 1,500 to over 2,000 have the least labor cost per bird.

The months of man labor per 100 birds in relation to the number of fowls per flock in the case of 150 poultry farms in New Jersey are shown in Fig. 213. The data in Fig. 213 show that as the number of fowls per flock increases, the months of man labor per 100 fowls decrease until a flock of approximately 1,500 fowls is reached.

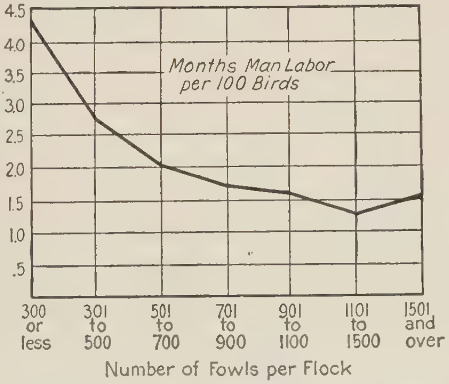

FIG. 213.—The relation of size of flock to labor expense on 150 poultry farms in New Jersey. (*App., Waller and Lewis*, 1918.)

FACTORS AFFECTING LABOR INCOME

Labor income, as defined by Vickers and Cray (1925–1926), means the net profit, or all receipts minus expenses except labor, the difference between receipts and expenses being the amount netted for the labor expended. Vickers and Cray also add the pertinent suggestion that "people keep poultry primarily to make money, and the factors that are responsible for greater profits should be known."

The chief factors affecting the labor income secured from farm and commercial poultry operations include the relative size of the poultry flock, egg production per bird, the proportion of pullets to yearling hens in the laying flock, the depreciation in the stock due to mortality and the elimination of non-profitable producers and prices of eggs in their relation to prices of feeds.

Relation of Size of Flock to Labor Income.—It is obvious, of course, that the larger the flock the greater the labor income, provided that the flock has been bred for high egg production and managed as efficiently as possible. As the result of a survey of economic factors affecting labor income on 150 poultry farms in New Jersey, App, Waller and Lewis (1918) submit the following table showing the relation between the number of hens per flock and profits on New Jersey poultry farms.

TABLE 94.—RELATION OF THE NUMBER OF FOWLS PER FLOCK TO PROFITS ON 150 POULTRY FARMS IN NEW JERSEY

(App, Waller and Lewis, 1918)

Number fowls per flock	Number of farms	Average number fowls per flock, Nov. 1, 1915	Average number hens per flock, Nov. 1, 1915	Cockerels per flock	Labor income	Labor income per hen
300 or less	19	255.7	249.1	6.6	$ 178	$0.71
301 to 500	42	446.2	437.5	8.7	313	0.71
501 to 700	29	621.2	607.8	13.4	423	0.69
701 to 900	23	842.5	823.7	18.8	779	0.94
901 to 1,100	12	1,025.5	998.0	27.5	1,387	1.39
1,101 to 1,500	17	1,338.8	1,308.8	30.0	1,668	1.27
1,501 and over	8	1,806.8	1,757.5	49.3	2,217	1.26
Average	150	736.8	719.8	16.9	$ 730	$1.01

Data have been given in Table 94 in terms of dollars and cents and, therefore, it is necessary to note at this time that although it has been considered advisable in this book to avoid as far as possible any discussion of various factors in terms of dollars and cents, because they vary so much from year to year, nevertheless, in some cases it is deemed advisable to discuss labor income factors in terms of dollars and cents because the relative values among the various factors probably still hold true.

The observations of the authors, therefore, are interesting:

> The labor income for these flocks increased with each increase in size of flock. The lowest labor income per flock was received on farms having less than 300

birds, while the highest was from the farms having over 1,500 birds per flock. These flocks have not, as a class, become too large for the greatest profit. The greatest profit per hen was obtained from flocks of from 900 to 1,100 birds. Larger than this, the profits per bird began to decrease. When smaller than this, the profits likewise decreased. From the standpoint of the individual hen, this was the most efficient unit, or size of flock. But for larger total profits per flock, a larger number of birds is necessary. The 8 farms having an average of 1,807 fowls per farm gave the largest labor income. How much more these flocks could be increased and bring a larger profit is not shown on these farms. It appears, however, that the profits per bird begin to decrease, since the labor income per hen is only $1.26 in the largest class, apparently as the result of the greater size of flock. Should a man wish to keep or develop a poultry industry of great size, it probably would be advisable to maintain units of a certain size, that is, about 2,000 fowls per unit or each unit large enough to keep two men busy throughout the year.

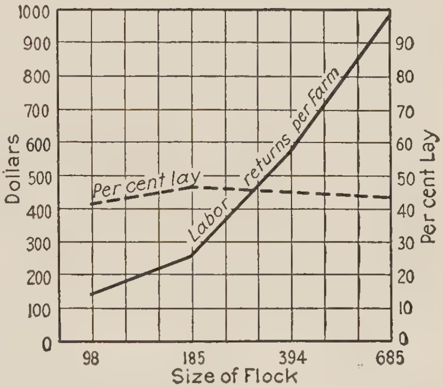

FIG. 214.—The influence of size of flock on labor returns per farm. (*Carver and Buchanan*, 1926.)

Figure 214 shows graphically the influence of size of flocks on labor income in connection with poultry flocks in the state of Washington, according to Carver and Buchanan (1926). Figure 214 shows that in the state of Washington as the size of flock was increased the labor income from the flock was increased.

The relation between size of flock and labor income is further shown in Table 95, data from Severance (1927) in the case of poultry farming in western Washington.

As in the case of the New Jersey poultry records, so in the case of the records of poultry farms in western Washington, the largest average labor incomes were obtained from flocks averaging approximately 1,000 to 1,500 hens.

Data are available showing the relationship between size of flock and labor income per farm and per bird on New York State farms. The data by Misner, Johnson and Marble (1927) are given in Table 96 for farms on Long Island and in Table 97 for other farms in New York State.

The data given in Tables 96 and 97 show that although the average labor income per farm increases as the flock is enlarged, the average labor income per bird apparently bears no relation to size of flock. The average labor income per bird ($2.28) from the 8 largest flocks on Long Island

TABLE 95.—RELATION BETWEEN SIZE OF FLOCK AND LABOR INCOME PER BIRD ON WESTERN WASHINGTON POULTRY FARMS

(Severance, 1927)

Number of birds	Number of farms	Average number of birds	Average total receipts	Average total expenses	Average farm income	Average labor income	Average labor income per bird
Oct. 1, 1923, to Oct. 1, 1924							
0 to 500.....	11	405	$1,949.39	$1,397.18	$ 552.21	$ 206.15	$ 0.51
501 to 1,000...	25	720	3,063.62	2,290.76	772.86	309.10	0.43
1,001 to 1,500...	12	1,212	5.021.72	3,259.99	1,761.73	1,264.78	1.04
1,501 to 2,000...	3	1,729	7,274.59	4,981.80	2,292.79	1,706.56	0.99
2,001 over......	2	3,250	12,150.96	9,317.04	2,833.92	1,985.98	0.61
All farms........	53	919	3,856.98	2,742.21	1,114.77	646.50	0.70
Oct. 1, 1924, to Oct. 1, 1925							
0 to 500.....	13	427	$2,672.49	$1,871.59	$ 800.90	$ 417.49	$ 0.98
501 to 1,000...	28	782	3,642.09	2,652.94	989.15	537.34	0.69
1,001 to 1,500...	12	1,235	5,731.29	4,019.68	1,711.61	1,235.04	1.00
1,501 to 2,000...	4	1,804	9,572.85	6,110.08	3,426.77	2,652.16	1.47
2,001 over.......	3	2,728	9,853.22	7,695.73	2,157.48	1,395.10	0.51
All farms........	60	960	4,555.79	3,239.61	1,316.18	834.79	0.87

TABLE 96.—RELATION BETWEEN SIZE OF FLOCK AND LABOR INCOME PER BIRD ON LONG ISLAND FARMS

(Misner, Johnson and Marble, 1927)

Number of birds per farm	Number of farms	Average number birds per farm	Average labor income per farm	Average labor income per bird
Less than 1,000......................	11	723	$1,436	$1.99
1,000 to 1,500.........................	13	1,120	1,512	1.35
More than 1,500.....................	8	2,383	5,450	2.28

TABLE 97.—RELATION BETWEEN SIZE OF FLOCK AND LABOR INCOME PER BIRD ON NEW YORK STATE FARMS NOT ON LONG ISLAND

(Misner, Johnson and Marble, 1927)

Number of birds per farm	Number of farms	Average number birds per farm	Average labor income per farm	Average labor income per bird
Less than 700..........................	40	523	$1,223	$2.34
700 to 1,200...........................	52	885	1,592	1.80
More than 1,200......................	29	1,872	2,361	1.26

is practically the same ($2.34) as from the 40 smallest flocks on other New York State farms. Various factors, such as egg production per bird, the proportion of pullets to laying hens, depreciation in the flock, prices received for eggs and cost of feed all have their effect in determining the results secured and undoubtedly all or some of these factors were effective in determining the results secured on the New York State farms.

The Relation between Egg Production per Bird and Labor Income.—It is obvious, of course, that the greater the egg production the greater the gross income secured. What is not fully appreciated, however, is the extent to which increased egg production adds to the net income secured. Suppose there are two hens, one of which consumes 75 lb. of feed and lays 90 eggs and the other consumes 80 lb. of feed and produces 185 eggs. Further suppose that in the case of the low producer, 80 eggs were required to pay for the 75 lb. of feed, and that in the case of the high producer, 85 eggs were required to pay for the 80 lb. of feed. The low producer has 5 eggs left and the high producer has 100 eggs left. Although total production is approximately in the proportion of 2:1, the proportion of eggs produced in excess of those needed to pay for feed is 20:1. It should also be observed that other cost factors in the case of the two hens, such as cost of rearing, housing, equipment and other items would be practically the same.

Data showing the importance of high egg production per bird in securing a good labor income are available from a variety of sources. App, Waller and Lewis (1918) give the data, shown in Table 98, which was obtained from 150 poultry farms in New Jersey, Nov. 1, 1915, to Oct. 31, 1916. The relative value of the average labor incomes shown in the right-hand column is the important thing to be considered, rather than the amount of the incomes.

TABLE 98.—RELATION BETWEEN EGG PRODUCTION PER HEN AND LABOR INCOME ON 150 POULTRY FARMS IN NEW JERSEY

(App, Waller and Lewis, 1918)

Eggs per hen	Number of farms	Average eggs per hen	Eggs sold per hen	Egg receipts per hen	Hens per farm	Average labor income
60 or less	9	46	46	$1.30	505	$ −176
61 to 80	13	68	66	1.90	673	− 67
81 to 100	32	91	88	2.30	650	312
101 to 120	53	108	104	2.90	785	775
121 to 140	27	126	120	3.40	717	1,173
141 and over	16	155	148	4.20	808	1,823
	150	109	103	$2.90	720	$ 730

In Table 99 are given data secured from 497 Ohio farm flocks by Cray and Zumbro (1926). Here again, instead of attaching significance to the cash value of each figure for labor income per bird, as given in the last two columns, its relative value in relation to egg production per bird is the thing of importance.

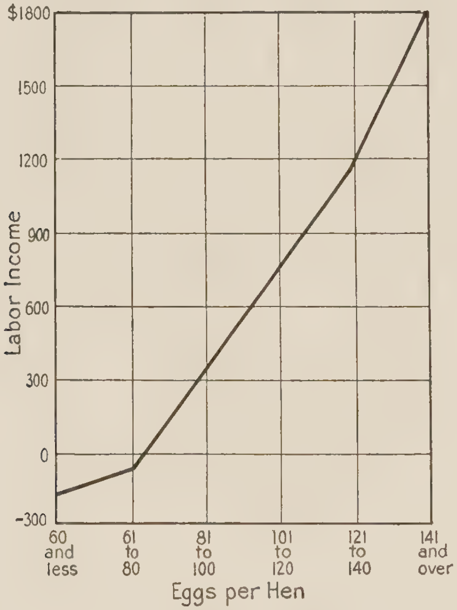

FIG. 215.—Relation of egg production per bird to labor income on 150 poultry farms in New Jersey. (*App, Waller and Lewis*, 1918.)

TABLE 99.—RELATION BETWEEN EGG PRODUCTION PER BIRD AND LABOR INCOME PER BIRD IN THE CASE OF 497 OHIO FARM FLOCKS

(Cray and Zumbro, 1926)

Production classification	Number flocks	Eggs produced per bird	Total expense per bird	Receipts per bird	Profit over feed per bird	Labor income per bird based on	
						Number hens beginning year	Average number birds
Leghorns:							
Under 100	5	92.4	$1.57	$2.65	$1.32	$0.28	$0.37
100 to 140	86	126.2	2.80	4.52	2.48	1.45	1.84
141 to 180	198	157.9	3.32	5.78	3.46	2.41	2.98
Over 180	36	186.5	4.08	7.48	4.78	3.26	4.23
All Leghorns	325	151.7	3.22	5.53	2.27	2.18	2.74
American Breeds:							
Under 100	13	89.7	$2.56	$4.27	$2.53	$1.31	$1.67
100 to 140	85	121.7	3.13	5.51	3.25	2.05	2.65
141 to 180	51	155.3	4.06	7.57	4.82	2.92	4.01
Over 180	5	189.2	4.54	8.74	5.76	4.55	5.95
All American breeds	154	132.3	3.41	6.14	3.75	2.34	3.08

TABLE 100.—RELATION BETWEEN EGG PRODUCTION PER BIRD AND AVERAGE LABOR INCOME PER FARM AND PER BIRD IN NEW YORK STATE

(Misner, Johnson, and Marble, 1927)

Production classification	Number of farms	Hens per farm	Eggs per hen	Labor income	
				Per farm	Per bird
Long Island:					
Less than 100 eggs	8	929	84	$ 273	$0.29
100 to 150 eggs	12	1,234	132	2,431	1.97
More than 150 eggs	12	1,672	174	3,975	2.38
Other New York farms:					
Less than 100 eggs	17	1,036	80	1,255	1.21
100 to 150 eggs	77	1,003	129	1,346	1.34
More than 150 eggs	27	979	167	2,786	2.85

TABLE 101.—RELATION OF EGG PRODUCTION PER HEN TO COSTS, RETURNS AND OTHER FACTORS, BY GROUPS OF FARMS, 1920 TO 1924

(Morison, 1928)

Item		Eggs per hen, annually		
		Under 60	60 to 100	100 and over
Farms	No.	7.0	7.0	8.0
Average hens per flock	No.	78.0	82.0	127.0
Total chickens per farm	No.	121.0	136.0	216.0
Annual egg production per hen	No.	48.0	83.0	115.0
Eggs sold, October to January, inclusive	Pct.	7.8	13.3	19.5
Nutritive ratio of feed, other than range	Lb.	1:8.4	1:7.8	1:6.9
Per 100 chickens, annually:				
Total concentrates fed	Lb.	4,707.0	5,616.0	6,336.0
Digestible nutrients in feed	Lb.	3,777.0	4,390.0	5,127.0
Digestible protein in feed	Lb.	448.0	560.0	743.0
Feed cost	Dol.	89.60	106.96	135.87
Labor	Hr.	163.7	188.9	201.6
Labor cost	Dol.	42.75	52.35	58.67
Total cost	Dol.	148.53	186.04	229.70
Total rêturns	Dol.	155.11	211.24	278.21
Returns above cost	Dol.	6.58	25.20	48.51
Eggs produced	Doz.	258.0	415.0	561.0
Eggs, value	Dol.	83.10	136.22	208.25
Meat, value	Dol.	72.01	75.02	69.96
Proportion of poultry receipts from eggs	Pct.	53.6	64.5	74.9
Cost of eggs per dozen	Dol.	0.308	0.289	0.306
Selling price of eggs per dozen	Dol.	0.322	0.328	0.371
Return per hour of labor on poultry	Dol.	0.30	0.41	0.53
Return per dollar's worth of feed	Dol.	1.73	1.97	2.05
Cost per dollar of returns from poultry	Dol.	0.96	0.88	0.83

In Table 100 are given the results secured on New York State farms as presented by Misner, Johnson and Marble (1927).

Morison (1928) gives a very interesting table showing the relationship between egg production per bird and several other factors on 22 farms in Medina county, Ohio, the data having been collected during the five-year period ended Dec. 31, 1924. (See Table 101.)

> Increased egg production per hen was accompanied by a larger proportion of eggs sold in the fall and winter, hence a higher average selling price. There was an increase in the amount of feed and a greater proportional increase in the amount of protein fed; the amount of labor expended per hundred birds was greater in the high producing flocks; and total costs per 100 chickens were about 50 per cent greater in the high producing than in the low producing group. The returns above all costs, however, were more than seven times as great for the high producers. From every angle the high producing hen was more profitable than the low producing one. (Morison, 1928.)

It has been shown that egg production per bird has an important effect in determining the average labor income per flock and the average labor income per bird. Relatively high average annual egg production means that more eggs are produced in the fall and early winter months than in the case of low average annual egg production. Jull (1923*a*, 1923*b*) has demonstrated that pullets commencing to lay in October

TABLE 102.—RELATION OF PERCENTAGE OF MONTHLY EGG PRODUCTION TO PERCENTAGE OF MONTHLY RECEIPTS PER FLOCK IN 36 NEW JERSEY COMMERCIAL FLOCKS, 1916, AND THE RELATION OF PERCENTAGE OF MONTHLY PRODUCTION PER BIRD TO PERCENTAGE OF MONTHLY PROFITS OVER FEED PER BIRD IN 400 MISSOURI FARM FLOCKS, 1923

("U. S. Dept. Agr. Yearbook," 1924)

Month	New Jersey		Missouri	
	Production per flock, per cent	Receipts per flock, per cent	Production per bird, per cent	Profit over feed per bird, per cent
November	3.20	5.50	3.26	4.75
December	4.30	7.10	3.82	5.04
January	6.50	7.70	6.52	6.98
February	8.50	7.80	7.24	7.07
March	12.80	10.00	12.81	10.37
April	14.10	10.40	12.17	10.16
May	13.70	10.30	13.28	10.99
June	11.30	9.40	10.42	8.02
July	9.70	9.70	9.15	6.82
August	9.10	7.60	8.03	7.77
September	4.90	6.90	7.48	12.19
October	3.10	5.40	5.89	9.71

are more profitable than pullets commencing to lay earlier or later. This is because the pullets that commence laying in October may be expected to avoid the fall neck and body molt and still maintain a relatively high percentage of production throughout the balance of their first year of production. Table 102 shows the monthly egg production as a percentage of total annual production in relation to the monthly receipts and profits as a percentage of the total receipts and profits for the year.

It is to be observed that in the months of September, October, November, December and January, in the case of both New Jersey and Missouri, the percentage of returns is greater than the percentage of production, which is not true of the other months of the year. This simply means that eggs are worth more relatively during the five months mentioned, and, consequently, production during this period has a relatively higher value than at other times of the year.

The Relation Between the Proportion of Pullets in the Laying Flock and Labor Income.—It has been shown on pages 122 and 124 that egg production decreases about 80 per cent each succeeding year that birds are kept. Since pullets lay more than yearling and older hens, it is interesting to determine the most economical proportion of pullets to have in the laying flock. Replacing the entire flock each year adds to the cost of replacement and, moreover, on most poultry plants some yearling and older hens are kept for breeding purposes. Then again, by eliminating the poor layers during the pullet year, the efficiency of the flock when the birds become yearlings is increased.

The relation between the proportion of pullets in the laying flock and labor income has been determined in a number of cases. Data from two sources are given in Tables 103 and 104.

TABLE 103.—RELATION BETWEEN THE PROPORTION OF PULLETS PER FLOCK AND LABOR INCOME ON 150 POULTRY FARMS IN NEW JERSEY

(App, Waller and Lewis, 1918)

Per cent pullets	Number of farms	Pullets per farm	Yearlings per farm	Cockerels per farm	Birds per farm	Per cent pullets	Labor income
50 or less.......	19	276	475	19	771	37	$ 511
50.1 to 60.......	37	450	405	19	874	52	1,034
60.1 to 70.......	36	556	309	23	888	64	1,062
70.1 to 80.......	32	470	172	16	659	73	445
80.1 to 90.......	12	412	83	8	503	83	430
90.1 to 100......	14	312	00	4	316	100	272
	150	442	278	17	737	61	$ 730

"The most profitable flocks contained 50 to 70 per cent of pullets. Consequently, according to these data the flock to be properly balanced should have 30 to 50 per cent of yearlings."

TABLE 104.—RELATION BETWEEN THE PROPORTION OF PULLETS IN THE LAYING FLOCK TO LABOR INCOME ON NEW YORK STATE FARMS
(Misner, Johnson and Marble, 1927)

Per cent pullets	Number of farms	Birds per farm	Eggs per bird	Per cent pullets	Labor income per farm
Long Island:					
Less than 60	11	1,311	133	55.0	$1,663
60 to 80	12	1,163	140	66.4	1,713
More than 80	9	1,466	157	88.1	4,467
Other New York farms:					
Less than 60	73	1,052	124	48.9	1,563
60 or more	48	926	140	73.4	1,793

The data in Table 104 show that on these New York State farms the higher the proportion of pullets the greater the egg production per bird and the greater the labor income per farm.

It is undoubtedly true that the proper proportion of pullets in a laying flock is determined very largely by the breeding quality of the birds, the poorer the breeding the higher should be the proportion of pullets.

Depreciation in the Flock.—The following pertinent observations are taken from App, Waller and Lewis (1918). "The depreciation of the birds is an item of much importance and should be carefully considered in holding over pullets and yearlings. A hen has a meat value and a laying value. The latter is potential and will almost always be greater than her meat value. Consequently, as hens grow older they decrease in potential egg-laying value and approach their meat value.

TABLE 105.—DEPRECIATION OF PULLETS AND YEARLINGS ON 100 POULTRY FARMS IN NEW JERSEY
(App, Waller and Lewis, 1918)

Kind of chicken	Value per bird	Depreciation per bird at end of year	Per cent depreciation per bird
Pullets	$1.53	$0.42	29
Yearlings	1.11	0.56	50
Two-year-olds	0.55		

By the time these pullets become two-year-old hens and are sold for meat, they depreciate from $1.53 to $0.55 or 64 per cent. During the first year of the pullet's life, she depreciates from $1.53 to $1.11, or 29 per cent. In the second year she depreciates from $1.11 to $0.55, or 50 per cent, when she is sold for her meat value. The death rate would further enter into this depreciation, but this presumably would be approximately the same for both pullets and yearlings.

Inasmuch as the yearlings depreciate $0.14 per hen more than pullets, it appears that they should lay 5.7 eggs more per hen (when eggs sell for 33.9 cts. per dozen) than pullets in order to be as profitable as the latter. This would be true were it not necessary to have a certain proportion of yearlings in the flock to act as a stabilizer and for breeding stock. Beyond the number necessary for that purpose no yearlings should be kept in the place of pullets. They lay fewer eggs per hen and depreciate more rapidly. However, if pullets at the end of the year had to be sold for their meat value, then their depreciation would be 64 per cent, or $0.98. In that case they would need to lay 2.9 doz. more (when eggs are selling at 33.9 cts. per dozen) than a 55-ct. hen in order to make the same profit.

On farms on Long Island, Misner, Johnson and Marble (1927) found that the depreciation in the pullets averaged 92.5 cts. per bird, in hens 59 cts. per bird, in males $2.61 per bird, and in the entire flock 85.3 ct. per bird per year. The depreciation in the flock comprised 17.6 per cent of the gross cost of producing eggs, the third largest item of the total cost, being exceeded only by the cost each of feed and labor. On the other farms in New York State it was found that the depreciation in pullets averaged 86.7 cts. per bird, in hens 49.1 cts. per bird, in males $3.82 per bird and in the entire flock 77 cts. per bird. The depreciation in the flock comprised 18.2 per cent of the cost of producing eggs, the third largest item next to feed and labor.

Besides the depreciation in the value per bird there is also a depreciation in flocks due to mortality. Losses in mortality in growing chicks have been given on pages 218 and 219 and it is only necessary to add at this time that on Long Island farms it was found that 74.5 per cent of the chicks hatched were reared to maturity and on other New York State farms 76.3 per cent of the chicks hatched were reared to maturity. Zumbro (1929) observes that in 1928 in Ohio the average percentage of chicks raised to 10 weeks of age in four breeds was as follows: Leghorns, 85.4; Plymouth Rocks 79.2; Rhode Island Reds, 71.4; Wyandottes, 66.4.

Carver and Buchanan (1926) give the per cent mortality in raising chicks and the number of pullets reared per 1,000 chicks hatched, as shown in Table 106.

It is realized, of course, that the per cent mortality of approximately 20 is far higher than necessary and constitutes an important source of depreciation in poultry profits.

The principal point of interest in this discussion, however, is the prevailing mortality in laying flocks. The per cent mortality in egg-laying contests in the United States has been reported by Jull (1925) as shown in Table 107.

TABLE 106.—PER CENT MORTALITY AND THE NUMBER OF PULLETS REARED PER 100 CHICKS HATCHED, THE STATE OF WASHINGTON

(Carver and Buchanan, 1926)

Year	Number of chicks reported	Per cent mortality	Number of pullets reared per 1,000 chicks hatched
1922	111,210	23.4	384
1923	283,736	22.8	387
1924	194,278	17.9	412
1925	204,656	16.5	419
Average	198,720	20.0	401

TABLE 107.—PER CENT MORTALITY IN LAYING CONTESTS IN THE UNITED STATES

(Jull, 1925)

Contest	1919 to 1920	1920 to 1921	1921 to 1922	1922 to 1923	1923 to 1924
A.	11.0	13.0	14.0	15.0*	11.1
B.	....	....	20.8	18.1	15.0
C.	23.9	13.9	12.3	17.7	18.2
D.	....	12.0	22.0†	22.0†	24.0†
E.	12.5	14.8	18.8	15.5	21.7

* Chicken pox and lack of green food supply.

† Chicken pox.

The fact that from approximately 11 to 24 per cent mortality is encountered in egg-laying contests should cause serious reflection on the part of poultry raisers in all parts of the country.

TABLE 108.—RELATION OF EGGS PER HEN TO SOME FACTORS WHICH INFLUENCE PROFITS ON 38 SONOMA COUNTY, CALIF., POULTRY FARMS. NOVEMBER, 1924 TO OCTOBER, 1925

(Buster and Fluharty, 1926)

	Group 1	Group 2	Group 3	Group 4	All farms
Number of farms	10	12	7	9	38
Size of flocks	1,980	1,675	2,135	875	1,651
Average number of eggs per hen	122	136	149	163	138
Per cent production	33.30	37.20	40.70	44.70	37.80
Per cent culled	21.10	31.70	28.20	38.10	28.70
Per cent mortality	22.40	19.70	21.20	13.30	20.10
Per cent replacements	42.50	46.40	43.60	48.30	44.80
Per cent added	56.60	39.80	36.90	52.40	45.70
Pounds grain and mash per hen	72.40	69.70	76.20	73.00	72.70
Pounds grain and mash per doz	6.88	6.17	6.14	5.40	6.21
Average price of eggs	35.30	36.70	38.60	34.30	36.40
Investment per hen	4.65	4.90	4.34	4.38	4.58

The rather high mortality that takes place in many commercial poultry flocks is shown in Table 108, the data being supplied by Buster and Fluharty (1926).

On farm flocks the mortality is also relatively high, as shown in the observations of Vickers and Cray (1925 and 1925–1926) and Cray and Zumbro (1926) in the case of Ohio farm flocks. In 1924 there was a mortality in the laying flocks of 12.1 per cent, in 1925 it was 13.8 per cent and in 1926 it was 11.1 per cent. The depreciation of the flock due to mortality is one of the principal factors of liability in poultry management and anything that will tend to decrease it tends to add to poultry profits.

THE RELATIVE PRICES OF EGGS, CHICKENS, FEED AND THE RELATIVE COSTS OF MARKETING EGGS AND CHICKENS IN DIFFERENT PARTS OF THE UNITED STATES

The prices of eggs and chickens vary considerably in different parts of the country; the price of feed also varies in different parts of the country, and, since the feed consumed by layers is such an important factor in determining the labor income from the farm or commercial flock, it is interesting to compare the relative prices of eggs, chickens, and feed in different parts of the country. It is also of value to compare the costs of shipping feed and eggs from one part of the country to the other. This is an important matter because the bulk of the feed used by poultry is produced in the so-called "corn and wheat belt" of the Middle West, and the greatest consuming market for poultry products is in the highly industrialized northeastern sections of the country.

The fact should be borne in mind that this discussion involving prices does not involve the effect of prices on profits in poultry raising, except indirectly. It is obvious that when egg prices are high and feed prices are low the profits in producing eggs are greater than when the reverse is true. On the other hand, it is true that high egg prices do not necessarily imply that poultry farmers are prosperous because feed prices may be relatively higher. Then again, the fact that high egg prices may curtail the consumption of eggs should be appreciated by all poultry raisers. The future development of the poultry industry depends largely upon two things: (1) the per capita consumption of eggs and poultry meat and (2) the degree of efficiency maintained in producing eggs and poultry meat. Both things are determined largely by the price of eggs, poultry meat and poultry feed.

Relative Prices of Eggs.—The price of eggs in different sections of the United States is of interest in determining the advantage that some sections may enjoy over other sections. It is to be expected that egg prices would naturally be relatively higher in the highly industrialized sections of the country than in other sections, a fact borne out by the data given in Table 109 from Davis (1924).

TABLE 109.—AVERAGE FARM PRICE OF EGGS IN DIFFERENT STATES, 1918 to 1923 (Davis, 1924)

	1918	1919	1920	1921	1922	1923
Connecticut	0.58	0.64	0.72	0.55	0.45	0.49
New York	0.51	0.56	0.61	0.46	0.40	0.40
Illinois	0.38	0.42	0.46	0.34	0.28	0.29
Nebraska	0.35	0.39	0.42	0.30	0.23	0.24
California	0.46	0.51	0.51	0.40	0.33	0.34
Georgia	0.35	0.40	0.48	0.31	0.26	0.30

The relative importance of the data given in Table 109 is discussed by Davis in the following terms:

> It is apparent from this that the yearly farm price in Connecticut has always exceeded the Illinois price by at least 20 cts. a dozen during the past six years. Not only is this true but the extent of our price advantage has been constantly increasing during this period as the following table will show:

TABLE 110.—PERCENTAGES WHICH THE FARM PRICE OF EGGS IN CERTAIN STATES ARE OF THE CONNECTICUT FARM PRICE

(Davis, 1924)

	1918	1919	1920	1921	1922	1923
Connecticut	100	100	100	100	100	100
Illinois	66	66	64	61	61	59
Nebraska	60	60	58	50	51	48
California	79	79	70	71	73	69

> The difference in farm price between Connecticut and Illinois is not all the direct result of nearness to market. Because of his location the Connecticut farmer sells about 31 per cent of his product direct to the consumer and 27 per cent to retail stores. Thus the Connecticut farm price includes payment for the performance of marketing service in many cases and for the production of a higher grade product. In fact, the Connecticut farmer produces almost entirely for the higher grades of the market and leaves the production of the great mass of storage and lower grade eggs to the corn belt which can produce them to sell at prices with which the eastern farmers do not care to compete.
>
> In comparison with our competitors we have higher production costs equivalent to a price of from 6 to 8 cts. a dozen. Deducting freight charges of 2 cts. per

dozen and assuming marketing costs otherwise to be equal, we possess a market advantage of about 20 cts. a dozen to offset a corn belt feed advantage of 4 to 6 cts. a dozen or an advantage of about 15 cts. a dozen. This is, however, for the very limited high grade market only. If our poultry industry should expand beyond the limits of this market for higher grade eggs it would have to compete on an entirely different basis. That this advantage of 15 cts. a dozen is somewhat reflected by market prices is demonstrated by the differences in the prices of fresh western as compared with local grades of eggs on the New Haven market.

TABLE 111.—AVERAGE YEARLY PRICES IN CENTS OF FRESH WESTERN, CONNECTICUT HENNERY, AND CONNECTICUT NEW LAID FANCY EGGS ON THE NEW HAVEN MARKET 1922 AND 1923

	1922	1923
Fresh western	41.7	41.7
Connecticut hennery	50.8	52.3
Connecticut new laid fancy	55.0	56.2
Difference between fresh western and Conn. hennery	9.1	10.6
Difference between fresh western and new laid fancy	13.3	14.5

The local [Connecticut] producer evidently can continue to expand his business and continue it permanently as far as his competitors are concerned as long as consumers continue to demand local eggs in preference to western eggs. If, however, even a small percentage of Central Western producers should develop high-grade egg production methods and effect a marketing organization capable of controlling the quality of their product, adequately financed for putting advertising and sales campaigns into the eastern cities to get control of the high grade demand, they would seriously threaten our market position and would probably succeed in considerably reducing the prices for high grade eggs.

How likely are they to actually do this? There is a slight tendency towards specialized poultry production in the corn belt today. Cooperative egg marketing organizations have been developed rapidly in that region in the past two or three years. They are likewise developing their own local markets for high grade eggs. The Extension organizations are bringing great pressure to bear to improve the quality of eggs, and methods of production and marketing throughout the region. On the other hand, the Central states are distant from our markets, a constantly lessening distance. Their farmers are primarily interested in beef, pork, and cereals and will tend to neglect hens when those industries are prosperous or the poultry business in a slump. The Central West lacks a body of poultrymen accustomed to and trained in the rigorous routine of producing high grade eggs. These latter facts will all serve to retard the speed with which the competition of this Central Western region becomes effective.

It seems likely that the competition of the Central Western states for the market for high grade eggs will become effective slowly and that if we make no progress to offset their gains they will gradually do what California has already done—successfully invade our market for the best eggs.

The relationship between the prices of fresh eggs on the Boston market as compared with other markets is shown in Table 112.

TABLE 112.—RETAIL FRESH EGG PRICES PER DOZEN IN CENTS COMPUTED FROM MONTHLY REPORTS OF *Monthly Labor Review*, U. S. BUR. OF LABOR (Davis, 1924)

	1923 yearly average	1922* yearly average	1921* yearly average	1920* yearly average	Four-year average	Per cent of Boston prices	
						Four-year average	1923 average
Boston, Mass.	65.8	63.2	72.2	90.6	72.9	100	100
New York, N. Y.	57.1	53.7	61.8	78.0	62.4	86	87
Providence, R. I.	61.7	59.5	69.2	87.4	69.4	95	94
Philadelphia, Pa.	49.2	47.0	54.0	71.7	55.4	76	75
Pittsburgh, Pa.	47.9	44.7	50.8	68.7	53.0	73	73
Chicago, Ill.	46.0	42.7	48.7	63.9	50.3	69	70
Houston, Tex.	36.1	35.1	39.0	56.8	41.7	57	55
Cincinnati, Ohio	40.3	49.6	45.7	61.4	46.7	64	61
Cleveland, Ohio	48.4	46.7	52.5	70.3	54.4	75	73
Minneapolis, Minn.	38.2	37.9	43.3	60.8	45.0	62	58
Milwaukee, Wis.	40.5	39.1	45.0	61.3	46.4	64	61
Kansas City, Mo.	39.2	36.9	43.2	60.5	44.9	62	59
Omaha, Neb.	36.7	35.3	41.0	58.5	42.8	59	56
St. Paul, Minn.	38.4	38.1	43.8	60.2	45.1	62	58
St. Louis, Mo.	39.8	37.9	43.0	60.3	45.2	62	60
Los Angeles, Calif.	46.5	44.8	50.2	64.5	51.5	71	71
San Francisco, Calif.	44.5	43.0	50.2	65.8	50.8	70	68
Seattle, Wash.	42.4	40.1	46.3	62.5	47.8	66	64
Atlanta, Ga.	41.4	38.3	44.6	62.5	46.7	64	63

* Yearly average retail strictly fresh egg prices secured from bulletins of U. S. Bur. of Labor Statistics.

From the data submitted in Table 112 it is apparent that the markets in the highly industrialized sections of the Northeast enjoy the advantage of relatively high egg prices.

That the quality of eggs is of importance in determining the price secured is borne out by the following charts and by the discussion of grades of eggs in relation to their relative value on pages 443 and 458.

Relative Prices of Feed.—Having considered the relative prices of eggs in different sections of the country, it is important to consider the relative costs of feed in the different sections of the country. Davis (1924) contributes the following information regarding the relative cost of feed in Connecticut as compared with other parts of the country. The important point to bear in mind is the *relative* price of feed in the different parts of the country rather than the actual price in any particular section. The fact should be appreciated that although feed prices vary from year to year the relationship among the feed prices of different parts of the country probably remains the same from year to year.

To properly appraise and compare feed costs in the corn belt and New England we must understand the nature of the poultry industry in each from the standpoint of the use of feed. Eastern poultrymen, whether farmers or specialized egg producers buy practically all their feed at retail feed stores or from retail cooperative units. Even the feed grown on the home farm in Connecticut is produced at a cost usually exceeding retail feed prices. The eastern poultryman's feed costs must be measured from the standpoint of current retail prices. In the East and West North Central states, on the other hand, approximately 75 per cent of the poultry feed consumed is grown on the home farm or in the immediate neighborhood. It is evident that three-fourths of the poultry feed costs in the North Central states must be based on farm prices of feed in that region. The following table shows 1923 farm prices of wheat, corn, and oats in the corn belt as compared with retail prices of the same feeds in Connecticut.

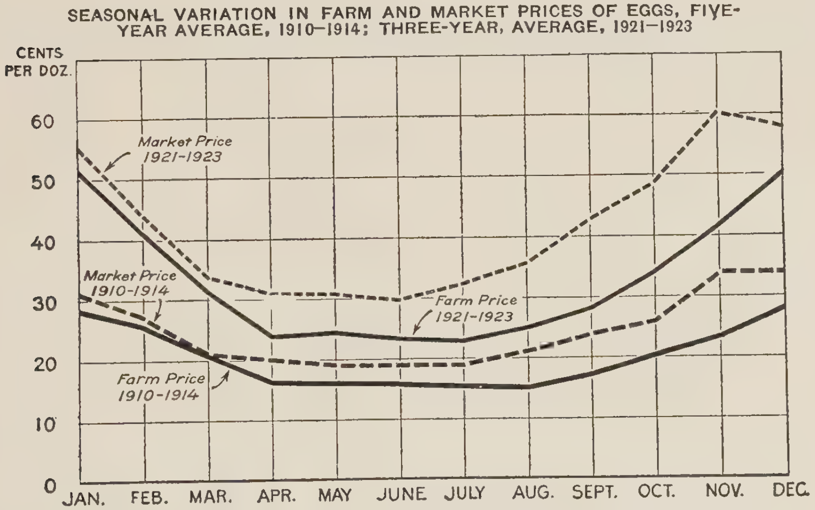

Fig. 216.—The farm price of eggs shown is an average of the prices received by producers in the States of Ohio, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri, Kansas, and Nebraska. The New York price is the wholesale price of fresh gathered firsts, a large part of which comes from the states named. The farm and market prices are very close together during the late winter and early spring, and gradually separate during the summer and fall until November, when they are farthest apart. This increase spread is doubtless due to the greater deterioration which occurs during the heated portion of the year and to the tendency of producers to hold eggs in the fall on a rising market. As a consequence, the quality of the farm eggs approximates less closely the quality purchased on the terminal market, so that the losses in candling and grading are greater and must be covered by the difference in the buying and wholesale prices. (*U. S. Dept. Agr.*)

TABLE 113.—1923 RETAIL PRICES OF GRAINS IN CONNECTICUT AND FARM PRICES IN THE CORN BELT*

(Davis, 1924)

	Corn per bu. of 56 lb.	Oats per bu. of 32 lb.	Wheat per bu. of 60 lb.
Connecticut average retail price per bushel	$1.16	$0.75	$1.55
Ohio average farm price	0.76	0.46	1.10
Illinois average farm price	0.66	0.37	1.03
Iowa average farm price	0.61	0.33	0.92

* Farm prices are taken from the estimates published by the U. S. Bur. Agr. Econ. in Weather, Crops, and Markets. Connecticut retail prices are computed by adding $5 to the car-lot jobbing quotations of Meech and Stoddard Co. of Middletown, Conn. Studies of margins in feeds made by Mehl in a large number of Connecticut towns show this to be approximately correct.

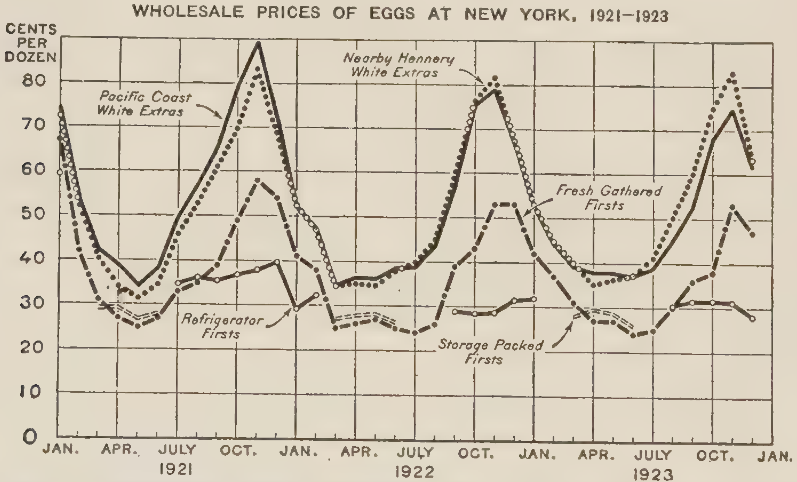

FIG. 217.—The prices of Pacific Coast white extras and nearby Hennery white extras show a very close agreement because of their high quality and the demand which exists for the product of such quality. The slightly higher price of the Pacific coast eggs in 1921 was doubtless due to the closer grading and greater uniformity of the eggs and the better packing. Since a quotation has been established on the New York market for New Jersey eggs as packed by the Producers' Cooperative Association of that State, the price of this grade has averaged higher than the Pacific coast eggs. Fresh gathered firsts, which are mainly eggs from the Middle West, exhibit the same general price tendency but range considerably lower, the difference in price being greater during the summer and fall than during the spring. The greater price spread during the former season is due to the greater difference in quality during the heated season and also to the fact that the users of this grade turn to storage eggs to a considerable extent when prices become high, which lessens the demand and tends to hold the prices lower. Storage packed firsts run several cents higher than fresh gathered firsts, owing to the more careful grading and better packing which are essential in eggs to be placed in storage. Refrigerator firsts, which are the storage packed firsts as they come out of storage, show a price level several cents higher than the latter, an increase which normally represents carrying charges and profit. The tendency is for the price of refrigerator firsts to rise during the fall and winter with that of fresh gathered firsts, but not to the same extent. (*U. S. Dept. Agr.*)

The differences by which western farm prices for 1923 were lower than Connecticut retail prices were as follows:

TABLE 114.—PRICE DIFFERENCES PER BUSHEL BETWEEN CONNECTICUT RETAIL PRICES OF GRAINS AND CORN BELT FARM PRICES

(Davis, 1924)

	Corn, cents	Oats, cents	Wheat, cents
Ohio	40	29	45
Illinois	50	38	52
Iowa	55	42	63

Computing these differences on a ton basis the advantages of the corn belt states over Connecticut are as follows:

TABLE 115.—DIFFERENCES BY WHICH CONNECTICUT RETAIL GRAIN PRICES ARE HIGHER THAN CORN BELT FARM PRICES ON A TON BASIS

(Davis, 1924)

	Corn	Oats	Wheat
Ohio	$14.20	$15.80	$15.00
Illinois	17.90	23.70	17.30
Iowa	19.60	26.25	21.00

Assuming a ratio of three parts corn, two parts oats, and two parts wheat by measure in the use of these feeds, we find that the Ohio farmers got their home grown feed, in 1923, $14.77 a ton cheaper than the Connecticut farmer buys his at the retail feed store. Illinois possessed a similar advantage of $18.80 a ton and Iowa of $21 in 1923.

The relative prices, for different states, received per bushel for corn and wheat, the two grains, together with their by-products, constituting the bulk of poultry rations, are given in Table 116.

TABLE 116.—1921 TO 1925 ESTIMATED AVERAGE PRICE OF CORN AND WHEAT PER BUSHEL RECEIVED BY PRODUCERS, DEC. 1*

	Corn	Wheat
New Jersey	81	127
Ohio	68	125
Indiana	61	123
Illinois	63	117
Minnesota	58	112
Iowa	59	108
Kansas	62	112
Missouri	69	117
New York	93	126
California	108	126
Pennsylvania	83	121
Tennessee	84	134
Washington	99	107

* U. S. Dept. Agr. "Yearbook 1926," Corn, p. 845; Wheat, p. 818.

FEED COST PER DOZEN EGGS AND NECESSARY SELLING PRICE

Card (1929a) presents an interesting chart whereby the feed cost per dozen eggs and the necessary selling price per dozen are readily determined when the cost of feed per 100 lb. and the number of eggs laid per 100 hens per day are known.

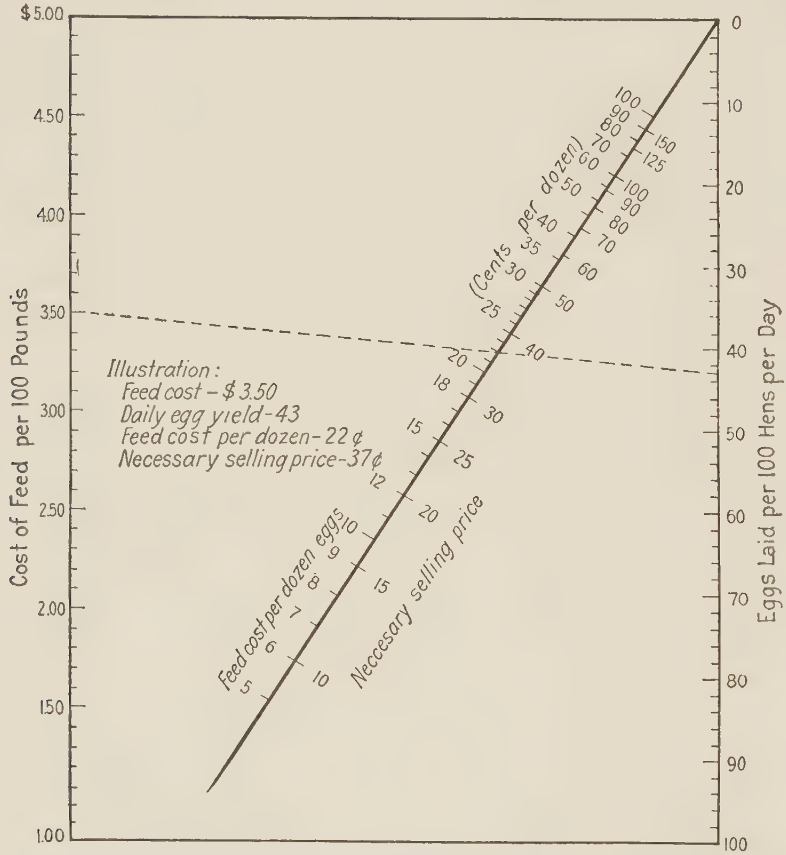

FIG. 218.—Calculation of feed cost per dozen and necessary selling price at varying feed prices and at various levels of egg production. It is assumed that 100 hens will consume 22.5 lb. of feed per day and that feed cost is 60 per cent of the total cost of production. (*Card*, 1929.)

The feed cost of eggs per dozen as produced by any given flock on any given day, assuming a food intake of 22.5 lb. per 100 hens per day, may be expressed by the equation $C = \frac{.225F}{E/12}$ in which F is the cost of feed per 100 lb. and E is the egg yield per 100 hens per day. It is obvious that this may be solved by simple arithmetic for any set of assumed or actual values of F and E. If, however, we set up a nomographic chart like Fig. 218, the solution is obtained for any set of values by simply laying a straightedge across the chart, connecting the proper values on the *F* and *E* scales, and intercepting the diagonal *C* scale at the required result.

On the assumption that feed cost represents 60 per cent of the total cost of producing eggs, a supplementary scale is easily added (Fig. 218) to determine the minimum or necessary selling price. Such a chart can, of course, be used in the reverse direction to determine the necessary daily egg yield to pay all costs under given conditions with respect to feed and egg prices. Once the chart is laid out there is no further mathematical calculating to be done for any variation in prices or production.

FEED PURCHASING POWER OF EGGS

The feed-purchasing power of eggs is discussed by Kempster (1929) in the following terms:

> The feed purchasing power of the eggs produced by a hen is of economic importance in determining the place poultry should play in a system of agriculture. Having the price of feed and eggs already determined, if one were to assume a certain egg production this relationship could be determined.
>
> In these calculations the prices for feed and eggs are the monthly farm prices as determined by the Missouri Office Bureau of Agricultural Economics, U. S. Department of Agriculture through the courtesy of Mr. E. A. Logan. The egg production values represent an eight-year average of the Missouri Demonstration Farm Poultry Flocks. Table 117 shows these figures.

TABLE 117.—DISTRIBUTION OF EGG PRODUCTION

(Kempster, 1929)

January	6.00
February	9.57
March	15.92
April	16.62
May	15.73
June	12.40
July	12.30
August	10.14
September	8.60
October	7.10
November	3.00
December	4.20
	121.60

The average price of a pound of feed is the average price of a mixture of 5 lb. of corn, 3 lb. of wheat and 3 lb. of oats. Thus for January, 1927,

500 lb. corn	@ $1.04 =	$ 5.20
300 lb. wheat	@ 2.06 =	6.18
300 lb. oats	@ 1.43 =	4.23
1,100 lb.	@ 1.42 =	$15.61

While this combination would not be considered a suitable ration for egg production, it represents practically the average farm cost of a ration which could be supplied that would adequately care for the hen's needs. Wheat is not extensively used in feeding poultry because of the high price, but this compensates for some more expensive feed which might be used to balance up the ration.

In general there is a strong tendency for egg prices to be high when feed is high, although the fluctuation in price of eggs is not so marked. Again, in 1917, 1918 and 1919 egg prices failed to rise as rapidly as did feed. One can remember the concern of poultrymen at that time. The high peaks in egg prices were just a year later than the high price of feed so that the poultryman found poultry keeping more profitable. In other words there appeared to be a lag in egg prices after a rise in feed prices, and the price of eggs failed to respond as quickly to the drop in feed prices.

Everyone is familiar with the seasonable distribution of egg production. There is a corresponding seasonable variation in the feed purchasing power of a hen's lay. It is interesting to note, however, that there is a tendency for the feed purchasing power to be relatively higher during the period from September to February when higher egg prices prevail. The monthly distribution of the feed purchasing power is shown in Table 118.

TABLE 118.—MONTHLY VARIATION IN POUNDS OF FEED A 122-EGG HEN WOULD PURCHASE, 17-YEAR AVERAGE

(Kempster, 1929)

January	11.2
February	13.0
March	17.4
April	17.1
May	15.8
June	12.0
July	11.9
August	10.6
September	10.8
October	11.3
November	6.1
December	8.5

A discussion has already been made relative to the relationship between feed and egg prices. The feed purchasing power of the eggs produced by a 122-egg hen shows a decline from 140 lb. in 1910 to 111 in 1915, and 112 in 1917. From 1918 this increased rapidly to 191 in 1921, from which high point it gradually dropped to 133 in 1924, rising again to 169 in 1926 and dropping to 141 for 1927. A study of this will show that in a number of years, there was a summer slump in the feed purchasing power of a hen's lay. This slump was usually of one or two month's duration. Such slumps are marked in the years 1920, 1921, 1922, 1925, 1926, and 1927, occurring in June for 1920, 1921, 1925, and 1927. In the years 1922 and 1926, the slump occurred in August.

Table 119 shows the general results for a period of 17 years.

Table 119.—General Summary for 17-year Period, 1910 to 1927 (Kempster, 1929)

Year	Price of feed	Pounds feed eggs would purchase (122-egg hen)	Price of eggs per dozen (122-egg hen)
1910	$1.28	140	18.4
1911	1.15	124	13.7
1912	1.36	132	18.0
1913	1.23	137	16.3
1914	1.38	132	18.0
1915	1.52	111	17.1
1916	1.58	128	19.1
1917	2.59	112	29.1
1918	2.75	119	32.7
1919	2.90	129	37.2
1920	2.82	142	39.3
1921	1.38	191	25.0
1922	1.31	163	20.7
1923	1.53	154	23.2
1924	1.71	133	23.0
1925	1.96	143	27.1
1926	1.50	169	25.0
1927	1.62	141	22.1

Using an estimated feed consumption of six pounds of feed per hen per month, it is interesting to note that in the ten-year period there are only four months in which a 122-egg hen did not lay enough eggs to more than pay for her feed. This fact should create confidence on the part of poultrymen in the stability of the poultry business.

From the feed-purchasing standpoint poultry keeping has been 12 per cent more profitable the last five years than during the prewar period from 1910 to 1914.

The problem of the poultryman is to secure greater egg production, particularly during the winter months. The importance of high winter egg production is shown by a comparison of a 93-, 122-, and 142-egg hen, respectively. During 1927 from Jan. 1 to Apr. 30, the eggs from a 93-egg hen would buy 37 lb. of feed as compared to 62 and 75 lb. for the 122 and 142 egg hens, respectively. Again, from July to December the eggs from the three respective types of hens would buy 44, 56, and 70 lb. of feed, while for the entire year the totals were 103, 141 and 168. It is safe to venture that the food consumption was not in the above proportion. Actual results from the Missouri Demonstration Farm Poultry Flocks show a gradual improvement in efficiency and where this is accomplished the poultry flock is on a firm economic basis.

TABLE 120.—POUNDS OF GRAIN THAT A DOZEN EGGS WOULD BUY AT U. S. FARM PRICES, GRAIN MIXTURE—ONE-HALF BUSHEL EACH OF CORN AND WHEAT[1]
(Waller and Weiss, 1927)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average[2]
Five-year average 1910 to 1914	23.9	20.5	16.7	13.1	12.6	12.1	12.4	12.8	13.9	16.4	19.5	24.2	15.4
1910	21.3	19.7	15.6	12.7	13.2	13.1	13.1	12.3	13.9	16.8	20.6	24.6	15.3
1911	25.8	18.4	14.2	13.0	12.5	11.9	11.5	12.1	13.4	15.0	17.4	22.2	14.6
1912	22.9	21.7	18.0	12.6	11.1	10.4	10.8	11.9	13.5	16.7	21.1	27.5	15.1
1913	24.8	20.2	17.0	14.4	13.5	13.6	13.6	14.0	14.8	17.7	21.6	25.8	16.4
1914	23.6	22.0	18.5	13.1	12.5	12.6	13.4	13.8	13.9	15.9	17.4	21.1	15.7
1915	21.1	16.7	11.8	9.3	9.1	9.2	10.8	10.6	12.6	16.0	19.6	23.7	12.7
1916	21.4	17.2	14.3	12.3	12.0	12.7	13.6	12.9	12.6	14.9	15.3	17.7	14.2
1917	18.2	15.9	14.8	10.2	8.8	8.8	8.5	8.1	10.0	11.5	13.2	15.2	11.4
1918	16.0	16.9	13.1	10.2	10.0	9.7	10.0	11.0	11.4	13.2	15.8	18.7	12.2
1919	19.0	16.2	11.1	10.9	10.9	11.2	10.7	11.2	12.2	14.3	18.1	20.6	12.8
1920	20.2	17.2	14.4	11.5	10.3	9.7	9.7	11.7	13.7	17.4	24.0	35.7	14.2
1921	32.8	27.1	16.0	12.0	13.7	11.8	14.7	18.5	22.4	25.3	37.8	43.7	19.5
1922	38.1	26.0	17.2	13.1	13.5	13.8	14.6	14.7	17.5	23.3	27.1	32.0	18.7
1923	29.3	22.3	19.6	13.8	13.6	13.2	13.3	15.5	17.5	21.0	24.9	33.7	18.0
1924	24.1	22.3	13.4	12.7	13.1	13.6	13.1	13.5	16.5	18.5	22.8	23.4	15.8
1925	20.6	14.6	10.0	11.5	11.2	11.5	13.2	13.5	14.8	19.9	24.2	24.9	14.1
Average 1910 to 1925	23.7	19.7	14.9	12.1	11.8	11.7	12.2	12.8	14.4	17.3	21.3	25.7	15.0

[1] *Farm Economics*, No. 31, Feb. 6, 1926.

[2] The yearly average is weighted by the seasonal production of 400 farm flocks on Missouri farms. The index numbers of seasonal variation in production being as follows: Jan. 78; Feb. 87; Mar. 153; Apr. 146; May 159; June 125; July 110; Aug. 96; Sept. 90; Oct. 71; Nov. 39; and Dec. 46. "Agriculture Yearbook," 1924, p. 405.

THE PURCHASING POWER OF EGGS AND CHICKENS

In a large measure the labor income of poultry raisers is determined by the quantity of various commodities that such a unit as one dozen eggs or one pound of poultry meat will purchase. The following discussion by Voorhies (1926) is of interest:

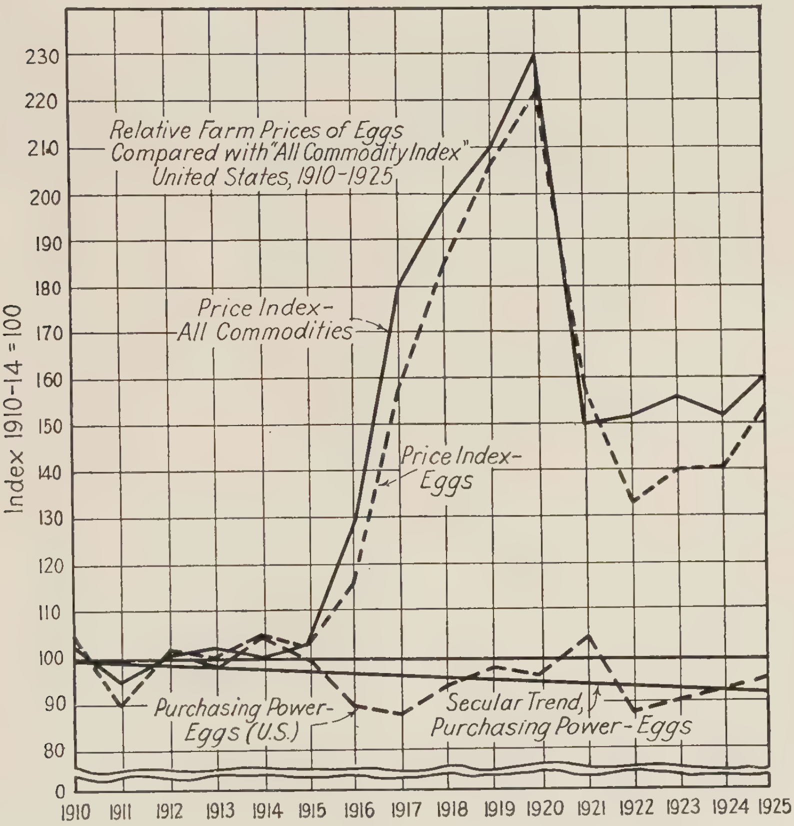

FIG. 219.—From 1910 to 1915 the price indices for eggs and all commodities were approximately the same. In 1916 the "All Commodity Index" began to advance more rapidly than the "Egg Price Index." The "All Commodity Index" remained above the "Egg Index" until 1921, when all commodities declined to a lower point than eggs. In 1922, however, eggs fell far below all commodities. (*After Voorhies*, 1926.)

High prices for eggs do not necessarily mean prosperity, nor low prices unprofitableness for the egg producer. If the prices received for eggs are high compared to the things the egg producer must buy, the poultryman is prosperous; if they are low compared with the things he must buy, he is not prosperous. Consequently, a comparison of the money prices of eggs and poultry and of the money prices of other commodities is of interest and value.

Figure 219 shows comparisons between the relative farm prices received in the United States for eggs and for all commodities, together with the "purchasing power" of eggs. This comparison is termed "purchasing power."

The index of wholesale prices compiled by the U. S. Bureau of Labor Statistics is used in converting prices of eggs to purchasing power. This index is now based upon the prices of 404 commodities. The purchasing power of eggs, therefore, indicates the value of eggs in exchange for all commodities, making up the commodity index of the U. S. Bureau of Labor Statistics at wholesale prices compared with prewar exchange values.

The purchasing power is often calculated by a comparison with non-agricultural commodities on the assumption that farmers exchange their products more generally for non-agricultural commodities than for" all commodities," as used in this publication. The poultryman in California, however, is a purchaser of agricultural as well as non-agricultural products. Owing to the intense specialization in the poultry districts of the state, the specialized poultryman

TABLE 121.—RELATIVE WHOLESALE PRICES AND PURCHASING POWER OF EGGS, UNITED STATES, 1910 TO 1925

(Voorhies, 1926)

Year	Actual price, cents per dozen I	Relative price II	All commodity index III	Purchasing power IV
1910	22.6	105	102.7	102
1911	19.4	90	94.7	95
1912	21.9	102	100.9	101
1913	21.5	100	101.8	98
1914	22.6	105	99.9	105
1915	21.9	102	102.6	100
1916	24.9	116	129.0	90
1917	34.2	159	180.3	88
1918	40.0	186	197.7	94
1919	44.3	206	210.1	98
1920	47.7	222	230.2	96
1921	33.3	155	149.6	104
1922	28.6	133	151.5	88
1923	30.1	140	156.5	90
1924	30.3	141	152.4	93
1925	33.5	156	162.0	96

Sources of data: Columns I and II, computed from the *Monthly Supplements to Crops and Markets*, U. S. Dept. Agr., Bur. Agri. Econ. The relative price is in this case obtained by dividing the actual price for each year by the average (arithmetical mean) of the prices for the five years 1910 to 1914. The average of the prices 1910 to 1914 is 21.6 cts. The relative price for 1910 is, therefore, 22.6 ÷ 21.6 = 105:1911, 19.4 ÷ 21.4 = 90, etc.

Column III, Bur. Labor Statistics index converted to a 5-year base (1910 –1914), published in the *Supplement to the Agricultural Situation*, Bur. Agr. Econ., June 1925, 54–62.

Column IV, computations by author. The purchasing power is found by dividing the Relative price by the All commodity index.

Current monthly statistics can be found in the *Monthly Supplement to Crops and Markets*, published by the Bur. Agr. Econ.

is perhaps more interested in the prices of agricultural commodities, such as feed, than he is in the prices of non-agricultural commodities. Standards of living are constantly changing. Expenditures are different today than they were five, ten or fifteen years ago. Too much stress should not be placed upon

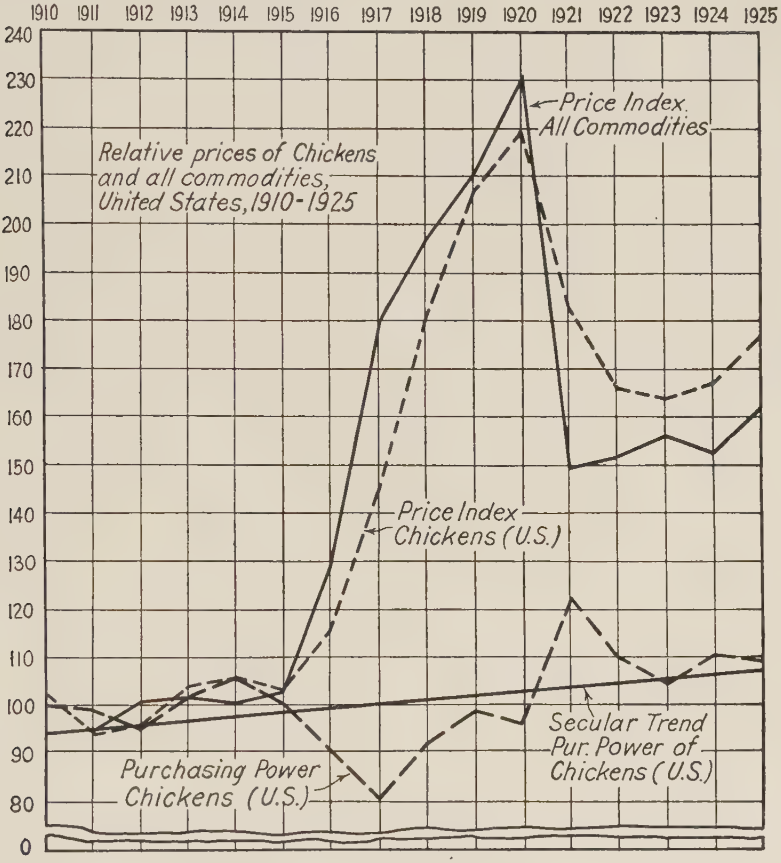

FIG. 220.—In the United States as a whole the relative prices of chickens and all commodities index were not far apart from 1910 to 1915. In 1916 the all commodities climbed more rapidly than the chicken prices. In the depression in 1921 the former declined more rapidly than the latter. Since 1921 the purchasing power of chickens in the country as a whole has been favorable. (*After Voorhies*, 1926.)

purchasing power as the "All Commodity Index" does not take into consideration many manufactured articles which have been actually cheapened by mass production.

Two types of changes are apparent in each of the curves in Fig. 219: (1) a long-time movement, and (2) short-time fluctuations. (1) Long-time changes are known as "secular trends." "The secular trend is that part of the fluctuation which is due to the gradual and persistent tendency to change which exists for an interval of several years, an interval the definite length of which cannot be assigned but which may extend over a generation and sometimes for a longer period." The causes of the secular trend are those which operate persistently year after year, such as increase in population, consumption and standards of living. (2) About the secular trend are cyclical fluctuations, which in the case of eggs, are rather irregular. In times of small profits, decreased production has usually resulted, flocks have been cut down, and underproduction has been brought about. If eggs are relatively high in price, chickens are raised in too large numbers, and, consequently, prices begin to fall as soon as there are too many laying hens.

From 1910 to 1915 (Fig. 219) there is a close correlation between the purchasing power of eggs and that of "All Commodities" in the United States. In 1916 "All Commodity" prices advanced more rapidly than egg prices and this lead was maintained until 1921 when the purchasing power of eggs exceeded 100 per cent (104) of the 1910 to 1914 average. In 1922, the purchasing power of eggs was at a disadvantage to the poultryman (88). The improvement has been marked since 1922, 1925 being only slightly under 100 per cent (96). Since 1910, in spite of the peak in 1921, the trend has been downward, the decline during the period 1910 to 1925 in the purchasing power being 7.2 per cent (trend values) on the basis of 1910 to 1914 average.

TABLE 122.—RELATIVE WHOLESALE PRICES AND PURCHASING POWER OF CHICKENS IN THE UNITED STATES, 1910 TO 1925
(Voorhies, 1926)

Year	Relative prices	Purchasing power	
	I	II	III
1910	103	100	98
1911	94	99	98
1912	96	95	96
1913	104	102	102
1914	106	106	105
1915	103	100	101
1916	116	90	93
1917	145	80	84
1918	181	92	98
1919	207	99	99
1920	220	96	94
1921	182	122	120
1922	166	110	108
1923	164	105	104
1924	167	110	110
1925	177	109	110

Source of data: Relative price from the *Bur. Agr. Econ.*, *Supplement to the Agricultural Situation*, June, 1925, and subsequent numbers of the *Bur. Agr. Econ. Agricultural Situation.* Purchasing power computed by dividing relative price by all commodity index (Bur. Labor Statistics).

The purchasing power of chickens in the United States is discussed by Voorhies (1926) in the following terms:

The trend of farm prices for chickens in the United States has been upward since 1910. Reference to Figure 220 will show that the relative chicken prices and the "All Commodity Index" are fairly close together until 1916, when the latter began to climb more rapidly. The greatest distance between the two indices was in 1917. Conditions were more favorable during the next three years, and in 1921 chicken prices remained higher than all commodity prices during the depression. Since 1921 the purchasing power of chickens in the United States has been above 100. It should be noted that the base used in computing the chicken price relatives is August, 1909, to July, 1914, while the "All Commodity Index" used is based upon the period January, 1910 to December, 1914 (columns I and II, Table 122 column III based upon calendar years 1910–1914).

THE COSTS OF SHIPPING FEED, EGGS AND CHICKENS AMONG VARIOUS PLACES IN THE UNITED STATES

The costs of shipping feed from the principal sources of grain production to various centres of poultry production have an important bearing on costs and profits in poultry raising in various parts of the country. Davis (1924) supplies the following data, revisions to date having been made, regarding freight rates on eggs and corn from various points of the country to points in the Northeast.

TABLE 123.—FREIGHT ALL-RAIL RATES IN CENTS PER 100 POUNDS*
(Davis, 1924, with revision to date by Hultgren, 1930)

From	To	Eggs	Cents per doz.	Corn
Springfield, Ill	Boston, Mass.	117½	0.02	43½
Springfield, Ill	Worcester, Mass.			
Springfield, Ill	Springfield, Mass.			
Champaign, Ill	Boston, Mass.	109	0.019	43½
Champaign, Ill	Worcester, Mass.			
Champaign, Ill	Springfield, Mass.			
Effingham, Ill	Boston, Mass.	114½	0.02	43½
Effingham, Ill	Worcester, Mass.			
Effingham, Ill	Springfield, Mass.			
Sandusky, Ia	Boston, Mass.	115½	0.02	46
Sandusky, Ia	Worcester, Mass.			
Sandusky, Ia	Springfield, Mass.			
Davenport, Ia	Boston, Mass.	115½	0.02	45
Davenport, Ia	Worcester, Mass.			
Davenport, Ia	Springfield, Mass.			
Muscatine, Ia	Boston, Mass.	115½	0.02	46
Muscatine, Ia	Worcester, Mass.			
Muscatine, Ia	Springfield, Mass.			
Sacramento, Calif	Boston, Mass.	225	0.052	
Sacramento, Calif	Worcester, Mass.			
Sacramento, Calif	Springfield, Mass.			
Fresno, Calif	Boston, Mass.	225	0.052	
Fresno, Calif	Worcester, Mass.			
Fresno, Calif	Springfield, Mass.			
Los Angeles, Calif	Boston, Mass.	225	0.052	
Los Angeles, Calif	Worcester, Mass.			
Los Angeles, Calif	Springfield, Mass.			
Hutchinson, Kan	Boston, Mass.	.....	.....	65
Hutchinson Kan	Worcester, Mass.			
Hutchinson, Kan	Springfield, Mass.			
Dodge City, Kan	Boston, Mass.	.....	.....	66½
Dodge City, Kan	Worcester, Mass.			
Dodge City, Kan	Springfield, Mass.			
Wichita, Kan	Boston, Mass.	.....	.....	64
Wichita, Kan	Worcester, Mass.			
Wichita, Kan	Springfield, Mass.			

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* All data on freight and express rates furnished by Thor Hultgren U. S. Dept. Agr., Bur. Agr. Econ., Division of Statistical and Historical Research Transportation, Feb. 14, 1930.

TABLE 124.—ALL RAIL AND RAIL AND LAKE FREIGHT RATES (EXCEPT AS OTHERWISE SHOWN) IN CENTS PER 100 LB.

(Davis 1924, with revisions to date by Hultgren, 1930)

From	To	Bran and middlings	Wheat
Buffalo, N. Y.	Boston, Mass	23½	
Buffalo, N. Y.	Worcester, Mass.		
Buffalo, N. Y.	Springfield, Mass.		
Buffalo, N. Y.	Chicago, Ill.	24	
Buffalo, N. Y.	Joliet, Ill.		
Buffalo, N. Y.	Danville, Ill.		
Rochester, N. Y.	Boston, Mass.	22½	
Rochester, N. Y.	Worcester, Mass.		
Rochester, N. Y.	Springfield, Mass.		
Rochester, N. Y.	Chicago, Ill.	33½	
Rochester, N. Y.	Joliet, Ill.		
Rochester, N. Y.	Danville, Ill.		
Milwaukee, Wis.	Boston, Mass.	40½[*]	
Milwaukee, Wis.	Worcester, Mass.		
Milwaukee, Wis.	Springfield, Mass.		
Milwaukee, Wis.	Chicago, Ill.	6½[†]	
Milwaukee, Wis.	Waukegan, Ill.		
Milwaukee, Wis.	Niles Center	20½	
Duluth, Minn.	Boston, Mass.	44	45
Duluth, Minn.	Worcester, Mass.		
Duluth, Minn.	Springfield, Mass.		
Duluth, Minn.	Chicago, Ill.	20½	22½
Duluth, Minn.	Englewood, Ill.		
Duluth, Minn.	Whiting, Ind.		

[*] Local, all rail.

[†] When originating beyond Milwaukee, all rail, 32½ cts. Local, all rail, 29½ cts. Originating beyond, 28½ cts. to Boston only.

TABLE 125.—EXPRESS RATES ON EGGS IN CENTS PER 100 POUNDS

(Davis, 1924, with revisions to date by Hultgren, 1930)

From	To Boston,	To Springfield,	To Worcester,
a Springfield, Ill.	311	300	311
Champaign, Ill.	200	200	200
a Effingham, Ill.	300	292	300
a Davenport, Ia.	326	311	326
a Muscatine, Ia.	356	334	356
b Sacramento, Calif.	506	506	506
b Fresno, Calif.	506	506	506
b Los Angeles, Calif.	506	506	506

a Second-class rates any quantity of 100 lb. or over.

b Car-load minimum 20,000 lb. rates from the origins, car-load minimum 30,000 lb., 450 cts.

Further information on the freight and express rates on eggs to New York City is shown in Table 126, from Waller and Weiss (1927).

TABLE 126.—FREIGHT AND EXPRESS RATES ON EGGS TO NEW YORK CITY, SEPTEMBER, 1926

(Waller and Weiss, 1927)

Station	Freight, case lots, cents					Station	Express, less than car lots, cents	
	Per 100 lb.	Per doz.	Station	Per 100 lb.	Per doz.		Per 100 lb.	Per doz.*
Pacific Coast:			Mid-West:					
Seattle, Wash.	260	4.5	Des Moines, Iowa	149½	2.6	Vineland, N. J.	109	1.7
Petaluma, Calif	260	4.5	Topeka, Kan.	185	3.1	Syracuse, N. Y.	116	2.2
Salt Lake, Utah	260	4.5	Bloomington, Ill.	104	1.7	Manchester, N. H.	139	2.4
Pocatello, Idaho	260	4.5	Washington, C. H., O	77½	1.2	Harrisonburg, Va	169	2.9
						Washington, C. H., O.	255	4.3
South:			East:			Bloomington, Ill.	292	5.0
Nashville, Tenn.	142½	2.4	Vineland, N. J.	40½	.7	Nashville, Tenn.	311	5.4
Fayetteville, Ark.	174	2.9	Syracuse, N. Y.	47½	.8	Des Moines, Iowa	360	6.2
Ft. Worth, Tex.	198	3.3	Harrisonburg, Va.	77½	1.2	Topeka, Kan.	405	6.9
			Manchester, N. H.	51	.9	Forth Worth, Tex.	517	8.9

* Cents per dozen figured at the rate of 52 lb. per 30-doz. case.

COSTS IN MARKETING EGGS

The costs of marketing eggs are determined by the method of marketing followed as well as by express and freight rates from point of shipment to the receiving market. Lininger (1927) conducted a survey of the costs of marketing eggs in Pennsylvania from July, 1925, to June, 1926, and found that "The farmers' marketing cost, when eggs were sold to hucksters, was 0.58 cts.; to country stores, 1.86 cts.; to consumers (house delivery), 4.30 cts.; and to New York wholesalers, 4.74 cts. per dozen."

Benjamin (1923)[1] made a close study of the costs of marketing eggs from the producer to the consumer through the regular channels of trade. His conclusions are as follows:

> Studies made by the author show the combined charge for the entire route, for distributing eggs from the producer to the consumer, to be about as follows, expressed in cents per 30-doz. case:[2]

Farm cost, distributive functions only	$0.30	to	$0.45
Huckster	0.30	to	0.60
Country store	0.15	to	0.30
Shipper, including cases and transportation	0.20	to	2.10
Receiver	0.30	to	0.75
Jobber	0.60	to	1.80
Retailer, without delivery	1.80	to	3.00
Total	$4.65	to	$9.00
Average per dozen	0.155	to	0.30
Storer, if eggs are stored	0 .75	to	1.00
Delivery to consumer	0.50	to	2.50

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[1] BENJAMIN, EARL W., "Marketing Poultry Products." By permission of John Wiley & Sons, Inc., publishers.

[2] Considerable range for costs by the various types of distributers is allowed, but the author does not believe this is any more than actually occurs in practice.

In the above estimate of costs, the lower costs are for cheaper eggs and those on which less service is expended. It is likely that the eggs on which $4.65 is expended sell at about 40 cts. retail to the consumer, while the eggs on which $9 is expended sell for about 80 cts. per dozen. The total cost of distribution under such an assumption is 38¾ per cent of the retail price for the 40-cts. eggs, and 37½ per cent for the 80-ct. ones. The total city costs for distribution, including the charges of receiver, jobber and retailer, but without delivery to the consumer, are 22½ per cent for the cheaper eggs, and 23¹⁄₁₀ per cent for the higher priced eggs.

Slocum (1924) has estimated the various ordinary costs incurred in marketing eggs from the producer until they are sold for the shipper's account by the wholesale receiver as follows:

	Cents
Loss in bad eggs	17
Cost of candling and grading	15 to 30
Loss on low-grade eggs	18¾
Loss on cracked eggs	1¼
Cost of new case and packing	45
Freight and icing charges	90 to 100
Drayage	5
Wholesale's commission	35 to 50

Total: $2.27 to $2.67 per case, or 7½ to 9 cts. per dozen.

Slocum says that if the eggs were placed in cold storage and held for a period of seven or eight months, an additional charge of from three to five cents per dozen in marketing costs would have to be added to allow for charges for storage space, insurance, interest on advances, possible rehandling, losses and cartage.

COSTS IN MARKETING CHICKENS

Benjamin (1923)[1] estimates the total costs of marketing live poultry as follows:

	Cost per Pound for Performing Marketing Functions
Farm, marketing functions only	$0.005 to $0.015
Huckster	0.01 to 0.02
Country store	0.005 to 0.01
Shipper, including transportation, use of coops and shrinkage	0.06 to 0.07
Receiver	0.01 to 0.02
Slaughter house	0.01 to 0.025
Retail butcher	0.05 to 0.08
Total	$0.15 to $0.24

Slocum (1924) gives the following costs of marketing live poultry in car lots from Missouri points to New York City:

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[1] Benjamin, Earl W., "Marketing Poultry Products." By permission of John Wiley & Sons, Inc., publishers.

	Cents, per Pound
Cost of receiving, handling, feeding, and loading at shipping point	1 to 1½
Freight, including live-car rental	2 to 2¼
Receiver's commission	1 to 2
Total	4 to 5¾

The costs of marketing dressed poultry have been estimated by Benjamin (1923)[1] to be as follows:

	Cost per Pound for Performing Marketing Functions
Farm (marketing functions only)	$0.005 to $0.015
Huckster	0.01 to 0.02
Country store (not often utilized)	0.005 to 0.01
Feeding station and shipper (including transportation, shrinkage, etc.)	0.035 to 0.06
Receiver	0.01 to 0.015
Jobber	0.02 to 0.03
Retailer	0.05 to 0.08
Total	$0.135 to $0.23
Storer (extra, if poultry is stored)	0.03 to 0.04

Slocum (1924) estimates the costs of marketing dressed poultry as follows:

	Cents, per Pound
Cost of handling poultry through the feeding station and dressing plant from the time it is received alive until it is loaded into the refrigerator car, ready to ship (This includes cost of handling, feeding, allowance being made for gains secured; killing and dressing, including dressing shrink; grading, packing, including cost of packages and supplies; and chilling)	4 to 8
Freight, including icing charges	1¾ to 2
Receiver's commission	1 to 1½
Total	6¾ to 11½

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[1] Benjamin, Earl W., "Marketing Poultry Products." By permission of John Wiley & Sons, Inc., publishers.

TABLE 127.—AVERAGE TRANSPORTATION COST PER POUND OF LIVE POULTRY SHIPPED BY FREIGHT AND BY EXPRESS TO NEW YORK CITY, BY ORIGIN, AVERAGE 1923 TO 1924 AND 1925 TO 1926[1]

(Buechel, 1929)

Origin	Cost of shipments by[2]	
	Freight, cents	Express, cents
Alabama	4.541	
Arkansas	5.152	
Atlanta, Ga	3.568	
Chattanooga, Tenn	3.822	
Chicago, Ill	2.839	
Connecticut	2.939	1.996
Georgia	3.762	
Illinois	3.300	
Indiana	2.475	
Iowa	3.172	
Kansas	4.931	
Kentucky	3.518	5.600
Maine	2.557	3.301
Maryland	3.667	2.482
Massachusetts	3.788	2.364
Michigan	5.640	
Minnesota	4.851	
Missouri	4.242	
Nebraska	4.571	
New Hampshire	.....	2.486
New Jersey	.....	1.850
New York	1.786	2.461
Ohio	2.252	
Oklahoma	5.367	
Pennsylvania	2.797	2.569
Philadelphia, Pa	1.900	
Rhode Island	.....	1.900
South Dakota	4.409	
Tennessee	3.535	
Texas	6.565	
Vermont	.....	2.942
Virginia	.....	3.068
Wisconsin	3.180	

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[1] Transportation costs include charges for freight, carman, feed, demurrage, stop-off and reconsignment privilege.

[2] Based on the net weight of car in New York City.

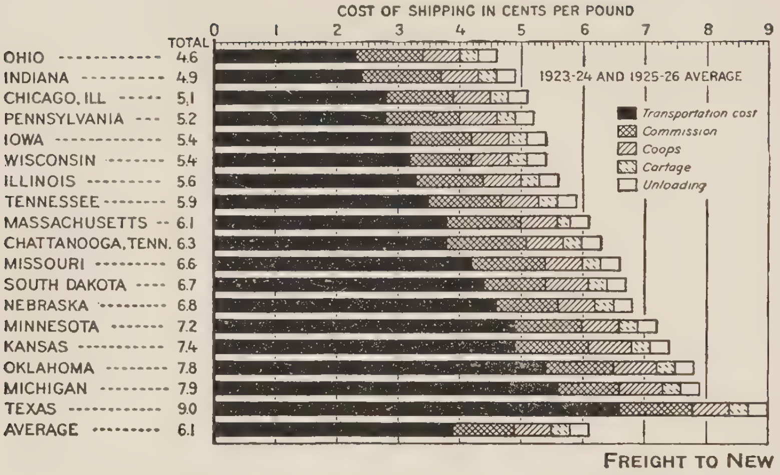

FIG. 221.—Cost per pound of shipping live poultry by freight to New York, arranged by source of origin. (*U. S. Dept. Agr.*)

TABLE 128.—COST OF SHIPPING LIVE POULTRY BY FREIGHT TO NEW YORK CITY, BY ORIGIN, AVERAGE 1923 TO 1924 AND 1925 TO 1926

(Buechel, 1929)

Origin	Cost per pound as received in New York City						Average net weight of carload, pounds	Total cost per car, dollars
	Transportation cost,[1] cents	Commission, cents	Coops,[2] cents	Cartage, cents	Unloading,[2] cents	Total, cents		
Illinois	3.30	1.14	0.64	0.27	0.32	5.67	16,668	945.08
Indiana	2.48	1.26	0.61	0.26	0.32	4.93	16,380	807.53
Iowa	3.17	1.04	0.61	0.26	0.33	5.41	15,951	862.95
Kansas	4.93	1.21	0.67	0.28	0.30	7.39	17,461	1,290.37
Massachusetts	3.79	1.18	0.58	0.24	0.35	6.14	15,105	927.45
Michigan	5.64	0.96	0.74	0.31	0.27	7.92	19,428	1,538.70
Minnesota	4.85	1.14	0.62	0.26	0.33	7.20	16,263	1,170.94
Missouri	4.24	1.20	0.65	0.27	0.31	6.67	16,956	1,130.97
Nebraska	4.57	1.09	0.61	0.26	0.33	6.86	15,943	1,093.69
Ohio	2.25	1.10	0.63	0.26	0.32	4.56	16,419	748.71
Oklahoma	5.37	1.18	0.70	0.30	0.29	7.84	18,417	1,443.89
Pennsylvania	2.80	1.24	0.60	0.25	0.34	5.23	15,652	818.60
South Dakota	4.41	1.02	0.67	0.28	0.30	6.68	17,417	1,163.46
Tennessee	3.54	1.24	0.62	0.26	0.33	5.99	16,149	967.33
Texas	6.57	1.20	0.64	0.27	0.31	8.99	16,830	1,513.02
Wisconsin	3.18	1.04	0.61	0.32	0.27	5.42	19,590	1,061.78
Chicago, Ill	2.84	1.09	0.64	0.27	0.32	5.16	16,668	860.07
Chattanooga, Tenn.	3.82	1.33	0.62	0.26	0.33	6.36	16,149	1,027.08
Average	3.88	1.02	0.63	0.27	0.33	6.13	16,700	1,023.71

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[1] Transportation cost includes freight, carman, feed, demurrage, stop-off and reconsignment.

[2] Based on present rates, rates were charged as follows: unloading, from $33 to $53 per car; coops, from 85 cts. to $1 per coop.

CHAPTER XXXII

RECORDS AND ACCOUNTS

It is only by keeping accurate records and accounts that poultry raisers can attain the greatest continuous success from year to year. Poultry production conducted on the basis of business principles requires that the poultry raiser know where he stands not only with others but also with himself. The keeping of records and financial accounts is a means of showing where money is spent, from what sources receipts are obtained, and where profits are made or where leaks occur.

Adams (1921) states that

> . . . the reason for keeping farm books usually rests in one or more of the following desires:
>
> 1. To determine the degree of profit that the business is making.
> 2. To suggest ways for increasing profits.
> 3. To provide an argument when soliciting loans.
> 4. To determine the details of farm investment, receipts, expenses and net income.
> 5. To determine the net returns from individual farm enterprises, for the purpose of detecting losses or indicating sources of greatest profit.
> 6. To furnish a memorandum of bills owed by or to the farm.
> 7. To provide a written record of operations for future guidance.
> 8. To furnish specific information, as the amount of feed fed to live stock, amount of production and efficiency of methods used in production.

The Advantages of Keeping Records and Accounts.—The outstanding advantage of keeping records and accounts is that it results in the poultry raiser giving much closer attention to details than would otherwise be the case. In the business of poultry production this is a very important matter because, since the chicken is such a small economic unit, the matter of detail is a very important factor in determining results secured. For instance, a simple thing, such as letting the brooder stove go out one night, may cause a high mortality in the chicks, or a window or screen in the laying house left open on a cold winter night may cause a material reduction in egg production. The proper attention to details in poultry management is of particular importance and the keeping of records and accounts serves to enlighten the poultry raiser regarding the relative importance of the various factors involved.

Other advantages in keeping records and accounts are that in a large measure they give the operator information which he would not possess otherwise and thus enables him to conduct his operations from year to year to the best advantage. Records and accounts to supply necessary information can be not only a means of increasing profits but also a source of pleasure and satisfaction by presenting concisely the financial status of the business.

Kinds of Records and Accounts to Keep.—The kind of records kept may vary from the taking of an annual inventory to a complete and detailed system of accounts for all branches of the poultry business. At least a sufficient number of accounts should be kept to enable the poultry raiser to determine whether his business as a whole is paying, and, if so, which branch of the business pays best. Each poultry raiser must decide for himself what kind of information he intends to get from his records and accounts.

Records and accounts may be simply records of things done and accounts of money transactions. The recording of things done from time to time throughout the year often proves of great value over a period of years. The accounting of money transactions, cash received and paid out, is of great value in teaching the poultry raiser from year to year the relative value of products sold and the relative value of feed and other things purchased.

Cost records should be kept and they should show the cost of labor, feed, poultry bought, equipment, supplies and other costs. Accounts should be kept showing the receipts obtained from eggs, market poultry, breeding stock and from other sources. Then, again, if poultry raisers would keep records of the mortality that occurs in their flock of growing chicks and in their laying stock, they would have greater appreciation of the importance of sanitation in reducing losses.

Table 129, from Adams (1921), illustrates three types of farm accounting from the most simple to the most complex:

TABLE 129.—TYPES OF FARM RECORDS
(Adams, 1921)[1]

Type	Records necessary	Information that may be obtained
I. Property record	1. Inventories made once a year	1. Investment in each kind of farm property and net worth of the farm as a whole 2. Increase or decrease in net worth during the year
II. Farm bookkeeping, accounts with the farm as a unit	1. Inventories made once a year 2. Financial records 3. Value of supplies furnished by the farm to the family 4. Value of board furnished by family to paid farm laborers 5. Unpaid family labor devoted to farm work	1. Investment in each kind of farm property and net worth of each farm as a whole 2. Increase or decrease in net worth during the year 3. Classified summary of farm receipts and expenditures 4. Farm income 5. Net farm profit 6. Household and personal expenses 7. Value of food, fuel and use of house furnished by farm to family
III. Farm cost accounts, with the farm and with each farm product and department as a separate unit	1. Inventories made once a year 2. Financial records 3. Value of supplies furnished by the farm to the family 4. Value of board furnished by family to paid farm laborers 5. Value of other perquisites furnished by farm to paid farm laborers 6. Unpaid family labor devoted to farm work 7. Labor record 8. Feed records 9. Live stock production records 10. Crop supply and yield records	1. Investment in each kind of farm property and net worth of to farm business as a whole 2. Increase or decrease in net worth during the year 3. Classified summary of farm receipts and expenditures 4. Farm income 5. Net farm profit 6. Household and personal expenses 7. Value of food, fuel and use of house furnished by farm to family 8. Cost per hour of man labor 9. Cost per hour of horse labor 10. Complete distribution of all costs 11. Complete distribution of all income 12. Complete allocation of all profits and losses 13. Cost of production in each department 14. Margin between cost and market value 15. Efficiency factors in farm management

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[1] ADAMS, R. L., "Farm Management," McGraw-Hill Book Company, Inc.

The Inventory.—The term "inventory" simply refers to entries once each year regarding the values of property, stock, feed, supplies and other things on hand at that time, together with a statement of cash on hand and money owed by and owing to the poultry raiser. The inventory thus gives information to the poultry raiser concerning his financial standing from year to year. Comparisons made of inventories taken from year to year show the poultry raiser the rate of progress or otherwise that he is making. The inventory, taken in conjunction with a cash account, shows how much has been made from the poultry business and to what extent this has been offset by personal and household expenses. A sample farm poultry inventory is shown in Table 130.

TABLE 130.—SAMPLE POULTRY FARM INVENTORY

Divisions and items of property	Jan. 1, 1929	Jan. 1, 1930
	Value, quantity per unit valuation	Value, quantity per unit valuation
Real estate:		
Land and improvements, acres		
Dwellings:		
House		
Poultry buildings		
Poultry:		
Layers		
Breeding stock		
Miscellaneous		
Feed:		
Corn		
Wheat		
Oats		
Mash		
Other feed		
Machinery and equipment		
Supplies		
Notes and accounts:		
Owed		
Owing		
Cash on hand		
Summary:		
Total assets		
Total liabilities		
Balance		

The Annual Statement.—The annual statement or final summary for the year is of great value in making out the inventory as well as in arriving at a proper appreciation of the volume and value of business undertaken.

TABLE 131.—GRAPHIC OUTLINE OF FARM SUMMARY OR ANNUAL STATEMENT
(Adapted from Adams, 1921, with changes)

	Item	Total
Investment:[1]		
Real estate		
Buildings		
Poultry		
Machinery and equipment		
Feed and supplies		
Cash to run farm		
Total		
Farm receipts:		
Sales: eggs, poultry, etc		
Other sources		
Feed and supplies accumulated during the year over the amount on hand at the first of the year		
Farm expenses:		
Operating		
Unpaid family labor		
Depreciation		
Decrease in feed and supplies taking place during the year over the amount on hand at the first of the year		
Total		
Farm income		
[2] Interest on investment at per cent		
Labor income		
Value operator's labor		
[3] Per cent return on investment		
Value of items for family use		

[1] Use average investment or that of beginning of year, whichever more nearly represents the true capital invested in the year's business.

[2] Use current rate of interest on well-secured farm loans.

[3] After deducting value of operator's labor from farm income.

TABLE 132.—ANNUAL STATEMENT OF NET WORTH

	Beginning of farm year	End of farm year
Resources:[1]		
All cash on hand		
Real estate		
Poultry		
Machinery		
Feed and supplies		
Household equipment		
Automobile		
Other tangible property		
Accounts owing to you		
Notes owing to you		
Mortgages owing to you		
Bonds and stock owned		
Interest due you or accrued on notes, mortgages, and bonds		
Total resources		
Liabilities:[2]		
Accounts owed by you		
Notes owed by you		
Mortgages owed by you		
Interest due or accrued and owed by you		
Total liabilities		
Total net worth:[3]		
Increase or decrease in net worth[4]		

[1] Includes all property owned by you and owing to you.

[2] Includes all amounts which are owed by you to someone else.

[3] Subtract total liabilities from total resources.

[4] If total net worth at the end of the year is greater than at the beginning of the year the difference is an increase; if less, a decrease.

Cash Accounts.—The keeping of cash accounts is of the utmost importance in enabling the poultry raiser to keep track of his various items of expense and receipts. The most satisfactory way of keeping cash accounts is by the double-entry system, where expenses are entered on one side of the page and receipts on the other side, as shown in Table 133.

TABLE 133.—CASH ACCOUNT

Date	Item	Dr. (receipts)	Date	Item	Cr. (expenses)
Jan. 10	Eggs, 90 doz. @ 50 cts.	$45.00	Jan. 6	4 tons mash @ $60	$240
Jan. 20	Eggs, 85 doz. @ 48 cts.	40.80	Jan. 28	5,000 egg cartons	60
Jan. 23	Capons, 70 lb. @ 40 cts.	28.00			

More detailed cash accounts of expenses and receipts may be kept in separate forms, with provision for showing the distribution of expenses and receipts among the more important items, as shown in Tables 134 and 135.

TABLE 134.—EXPENSES

Date	Item	Unit price	Amount	Distribution among items			
				Feed	Labor	Equipment	Miscellaneous
Jan. 10	6,000 lb. scratch feed	$2.25	$135.00	$135			
Jan. 10	6,000 lb. mash	2.50	150.00	150			
Feb. 18	5,000 egg cartons	1.20	60.00	....	...	...	$60.00
Mar. 1	Labor for February	.....	50.00	....	$50		
Mar. 31	10 mash hoppers	4.00	40.00	....	...	$40	
May 1	Express on eggs	.....	13.50	....	...	...	$13.50
Nov. 1	50 bales straw	0.50	25.00	....	...	...	$25.00

TABLE 135.—RECEIPTS

Date	Item	Unit price	Amount	Distribution among items			
				Market eggs	Hatching eggs	Market poultry	Breeding stock
Jan. 5	100 doz. eggs	$0.60	$ 60	$60			
Mar. 13	1,000 hatching eggs	0.10	100		$100		
May 10	500 broilers, 1,000 lb.	0.28	280	...	....	$280	
Oct. 12	300 roasters, 1,200 lb.	0.25	300	...	....	300	
Nov. 1	50 breeding cockerels	4.00	200	...	....	....	$200
Nov. 18	80 doz. eggs	0.45	36	36			
Dec. 4	100 doz. eggs	0.55	55	55			

Other records.—The poultry raiser may wish to keep records for various projects in his poultry business. Because of the fact that feed is the most important single factor of cost in producing eggs, it is often desirable to keep a monthly record of the amount and cost of feeds consumed and the number and value of eggs produced. A convenient form for keeping such records is shown in Table 136.

TABLE 136.—MONTHLY FEED COST AND EGG VALUE RECORD
(U. S. DEPT. AGR.)

Date	Feed								Eggs			Dead
	Scratch Grain	Mash	Grit	Shell	Gr. F.	Milk	Misc.	Total	No.	Price	Value	
On h												
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
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31												
Tot.												
W. B.												
Amt.												
Avg.												
Pr.												
Value												

PEN NO. ____

BREED ____

PULLETS, HENS ____

MALES ____

TOTAL ____

MONTH ____

Average amount feed per dozen eggs ____

Average cost per dozen eggs ____

Average cost feed per bird ____

Average profit or loss per dozen ____

Average profit or loss per bird ____

Average number birds ____

Number and date males introduced ____

Number and date males removed ____

The summarized statement of feed costs and egg values obtained for each month in the record shown in Table 136 may be entered in the record shown in Table 137, thus giving a complete picture from month to month and for the year of the revenue in egg production over feed costs.

TABLE 137.—ANNUAL FEED-COST AND EGG-VALUE RECORD

(U. S. Dept. Agr.)

Pen No. .... Variety .... No. Pullets, Hens........ 19— 19—

Month	Amt. feed cons.	Ave. amt. feed cons.	Ave. cost feed per bird	Eggs laid	Ave. number eggs laid	Ave. price per doz.	Ave. amt. feed per doz.	Ave. cost per doz.	Ave. profit or loss per doz.	Ave. profit or loss per bird	Feed value	Egg value	Loss over feed	Profit over feed	Net revenue	Mortality
Aug																
Sept																
Oct																
Nov																
Dec																
Jan																
Feb																
Mar																
April																
May																
June																
July																
Aug																
Sept																
Oct																
Total																
Ave. per mo																
Ave. per bird																

In concluding this chapter on Records and Accounts, too much emphasis cannot be placed upon the importance of keeping such records of expenses and receipts as to enable the poultryman to conduct his poultry enterprise in the most efficient manner possible. The keeping of records provides information of great value in management problems and frequently means that profits are made instead of losses being sustained. It is only by keeping a proper set of records that any poultryman can hope to make the greatest success in poultry production.

CHAPTER XXXIII

POULTRY PLANT LAYOUTS

The layout of the poultry plant, whether on the farm or otherwise, has an important bearing on the results secured from year to year. The location and arrangement of the buildings determine to a much greater extent than most people realize the results secured in raising chicks and in the number of eggs produced by the laying stock.

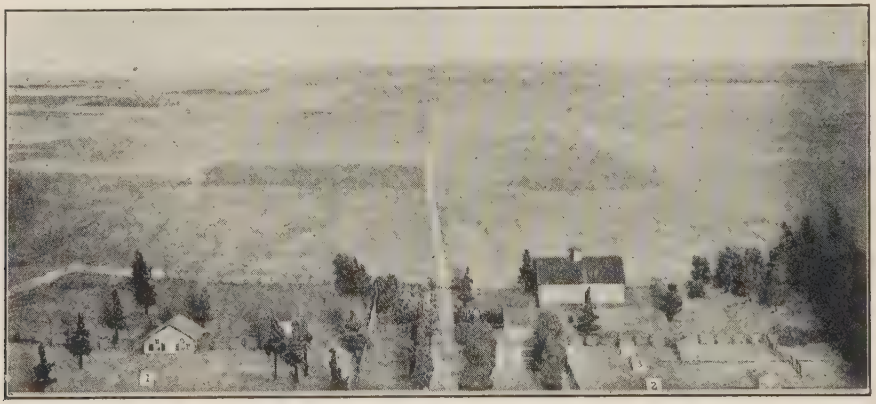

FIG. 222.—The poultry plant on this 160-acre farm is laid out as a separate unit from the rest of the farm. The poultry is thus kept separate from other classes of livestock, and the chicks are reared apart from the adult birds. Alternate range for both laying hens and growing chicks reduces mortality. 1 and 1, laying hens have separate unit of 1.7 acres; range is divided into two equal parts; each range field is cultivated and sown to a green crop every other year. 2 and 2, chick range is also alternated. 3 and 3, colony brooder stoves are used for brooding. Sanitation on range and in houses is absolutely necessary for best results. (*U. S. Dept. Agr.*)

The poultry part of the farm organization should be regarded as a separate unit and should be treated as such. The farm flock of chickens should be kept separate from all other classes of live stock and the growing chickens should be brooded and reared separately from the adult laying stock. On most commercial poultry plants this practice is followed to a large extent, but on farms it is too frequently the practice to raise the chickens with the adult stock and allow all to have free access to the barn, horse and cow stables and pig pens. Under such circumstances there is liable to be excessive mortality from worms and disease. On the other hand, on commercial poultry plants, it is too frequently the case that chicks are reared on the same ground year after year and laying birds are kept on the same range year after year, so that mortality from worms and disease is excessive. The proper arrangement of brooding and laying houses and the proper yarding arrangements will largely overcome excessive mortality.

The essential features to be kept in mind in the poultry plant layout, whether on the farm or the commercial poultry plant, are sanitation, convenience and attractiveness. Providing proper sanitation is the best investment in reducing losses. Convenience in respect to the proper location of the buildings saves labor. Attractiveness is a very valuable asset, especially where eggs, live or dressed poultry, baby chicks and breeding stock are sold on the premises.

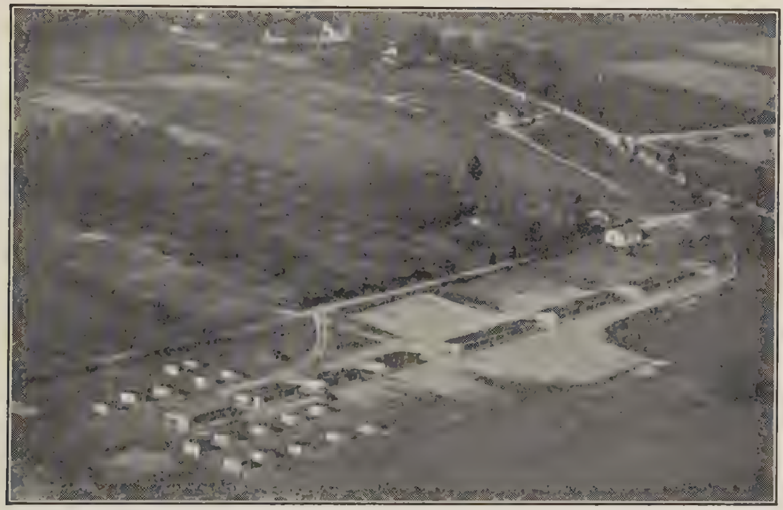

FIG. 223.—Airplane view of the well-laid-out Butler poultry plant in New Jersey, showing well-arranged houses to provide good range. (*Photograph by Everybody's Poultry Magazine.*)

Sanitation in Poultry Plant Layouts.—Sanitation is provided by having clean range for the growing stock as shown in Fig. 224 and for laying stock as shown in Fig. 226. The importance of clean range for the growing stock is discussed in Chaps. XV and XXVI so that here it is only necessary to emphasize particularly the importance of providing proper sanitation for the laying stock. In this respect, the following observations made by Jull and Lee (1928*b*), with additions, are pertinent. Laying fowls should be confined to good-sized yards adjacent to the laying house rather than allowed to roam over the premises, because the layers can be managed more efficiently and they should not be allowed with the cattle and hogs. The value of fresh, sweet land for poultry can hardly be overestimated, and the yards should be large enough so that they can be cultivated and sown to a grass or other green crop.

A good grass sward can be maintained on fertile soil by allowing from 220 to 260 sq ft. of land per bird (200 to 167 birds to the acre). More space per bird is necessary on poor grassland. A much larger number of fowls is usually kept to the acre on sandy soil, where double yards are used and the land is frequently cultivated. Under this system as many as 1,000 laying hens are sometimes kept on 1 acre, for egg production only, when the stock is not used for breeding and no chicks are raised.

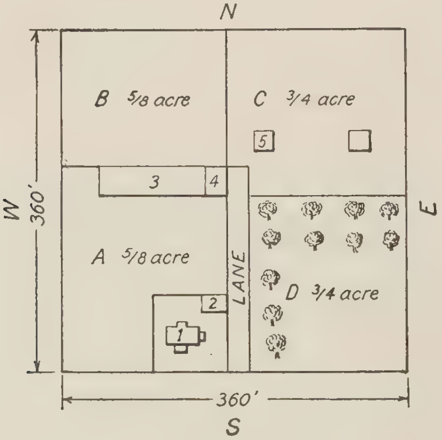

Fig. 224.—A layout for a 3-acre poultry plant which will accomodate 500 layers. *A* and *B* are alternate yards for the laying house. *C* is one range for the young stock and *D* is another range that is used alternately with *C*. The numbers represent the buildings as follows: 1, dwelling; 2, garage; 3, laying house; 4, feed room; 5, colony brooding houses. (*Amer. Poultry Jour.*)

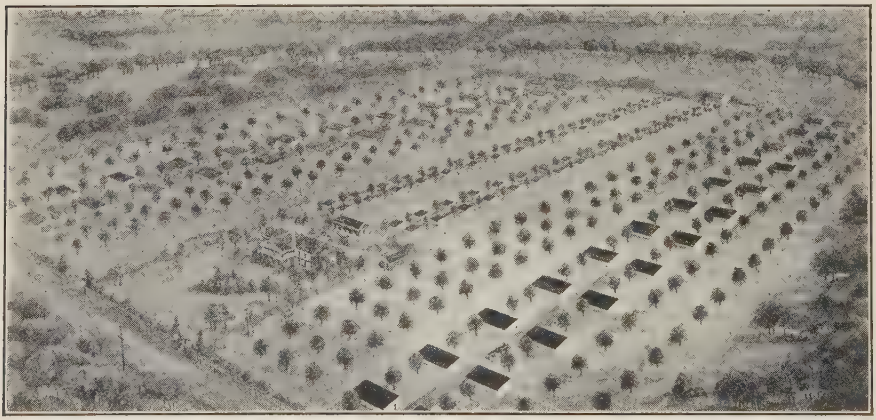

Fig. 225.—On the Johnson farm in Texas the houses for the chicks and the breeding and laying stock are located on the driveways. System and convenience mean much for success on a poultry plant. A double-yarding arrangement is provided for each house. (*Photograph by Mr. M. Johnson.*)

A desirable arrangement of yarding, especially where green feed can be grown throughout the year, is to have three yards of equal size for each house, one in front and two in the rear, the rear yards extending beyond the house. The single yard in front makes fewer gates to open and close in going to and from the house. The birds may be alternated from yard to yard and a green crop grown in each yard as soon as it is vacant. The three-yard arrangement for laying stock was developed by J. E. Ivey, formerly head of the Poultry Department of the Alabama College of Agriculture. In the South where it is possible to grow green feed the year round the three-yard system of providing range for the laying stock is especially recommended. In the northern sections of the country, where the laying stock is naturally confined for about five months of the year, the double-yarding system is recommended.

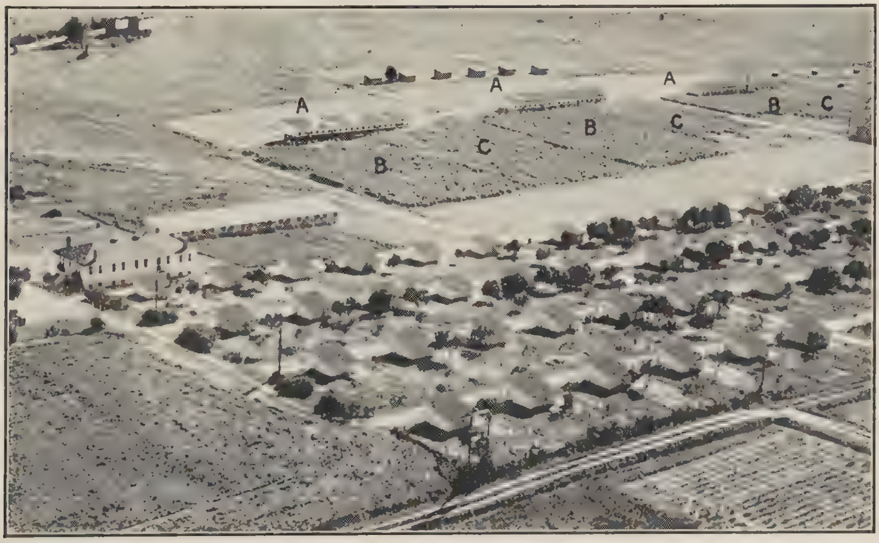

Fig. 226.—A three-yard system for yarding the laying stock. The photo includes in the foreground the houses used in the Alabama egg-laying contest and other buildings on the poultry plant of the Alabama Agricultural Experiment Station. In the upper portion of the picture there are shown three laying houses, each provided with three yards, *A*, *B*, and *C*, all of the same size. Such an arrangement allows for rotation in using the yards and thus tends to keep mortality to the minimum. *(Photograph by Ala. Agr. Exp. Sta.)*

The general-purpose and meat breeds require fences from 5 to 6 ft. high, while for Leghorns a fence from 6 to 7 ft. high is necessary. To keep Leghorns in, it may help to slant the upper 2 ft. of the fence in at an angle of about 30 deg. A strand or two of barbed wire strung on top of the woven wire is desirable. It is sometimes necessary to clip the flight feathers of one wing of any bird which persists in getting out. A board or wooden strip along the top of the fence is not advisable, because hens will fly up to it.

Posts may be set or driven. They should be from 8 to 10 ft. apart for common hexagonal poultry netting or 16 to 20 ft. for woven wire. Woven-wire fencing makes a better looking fence and will last much longer than the common poultry netting. Corner posts should be about 8 in. in diameter, set 4 ft. in the ground, and they may be set in concrete or braced, or both. Line posts may be 4 or 5 in. in diameter, set 3 ft. in the ground. Creosoting the ends that will be below ground or treating them with some other preservative will make the posts last longer.

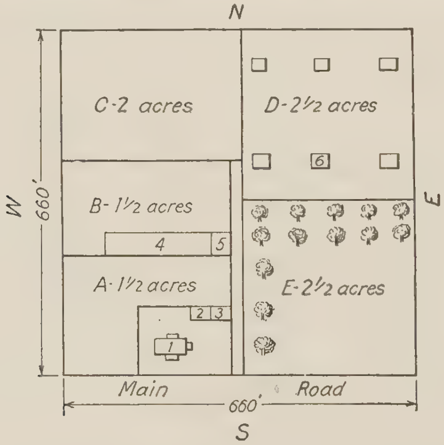

Fig. 227.—A layout for a 10-acre poultry plant which will accomodate 1,600 to 2,000 layers. *A* and *B* are alternate yards for the laying house. *C*, *D*, and *E* are ranges for the young stock used on a 3-year rotation system.

The numbers represent the buildings as follows: 1, dwelling; 2, garage; 3, service room for packing eggs, etc.; 4, laying house; 5, feed room; 6, colony brooder houses. (*Amer. Poultry Jour.*)

Convenience in Poultry Plant Layouts.—The houses should be located as conveniently as possible in order to save labor. At the same time, as pointed out on page 263, financial returns from the flock are often sacrificed in order to have the brooder and laying houses near the living house. Although there are advantages in having poultry houses located in the shelter of other buildings, proper yarding arrangements should be provided unless the chicks are brooded in confinement and the laying stock is kept in confinement the year round.

In arranging the fences for poultry yards great care should be taken to allow all parts of the yards to be cultivated readily. This is very important because disease germs and parasite eggs lurk in corners that are not cultivated from time to time. Colony houses may be located along the roadway as shown in Fig. 225 or they may be located in the center of the yards as shown in Fig. 227. The latter is a better looking and more sanitary arrangement, although there are gates to be opened and closed. On the other hand, when the houses are located along the roadway, the door of each house must be kept closed.

It is important to have the water supply convenient. A little ditch digging and plumbing to put the water tap in or near the poultry house will save many steps over a period of years. In the case of colony houses a water tap can be located at every fourth house, thus enabling the attendant to carry two pails of water to two houses the other side of the one where the tap is located.

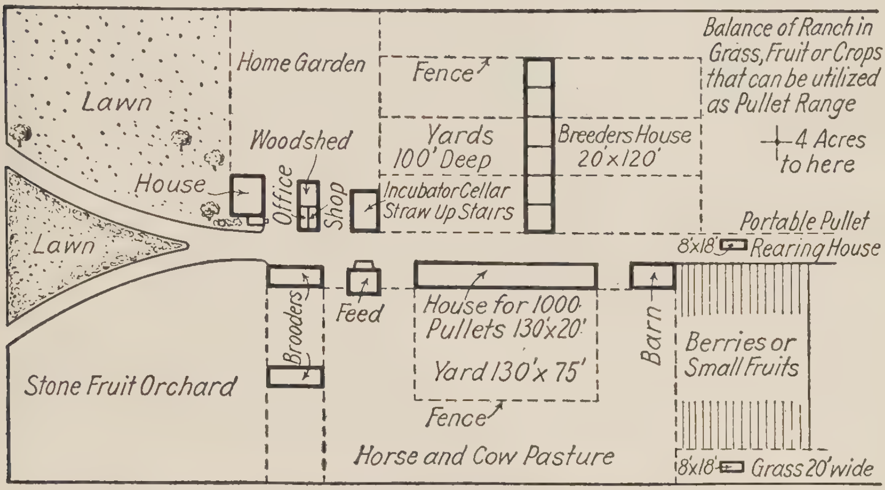
Lawn
Home Garden
Fence
Balance of Ranch in Grass, Fruit or Crops that can be utilized as Pullet Range
Woodshed
Yards 100' Deep
Breeders House 20'×120'
4 Acres to here
House
Office
Shop
Incubator Cellar Straw Up Stairs
Portable Pullet
8'x18'
Rearing House
Lawn
Brooders
Feed
House for 1000 Pullets 130'x20'
Yard 130'x 75'
Barn
Berries or Small Fruits
Stone Fruit Orchard
Fence
Horse and Cow Pasture
8'x18'
Grass 20' wide

FIG. 228.—Plan of a 10-acre poultry plant. (*Plan by Wash. State Agr. Exp. Sta.*)

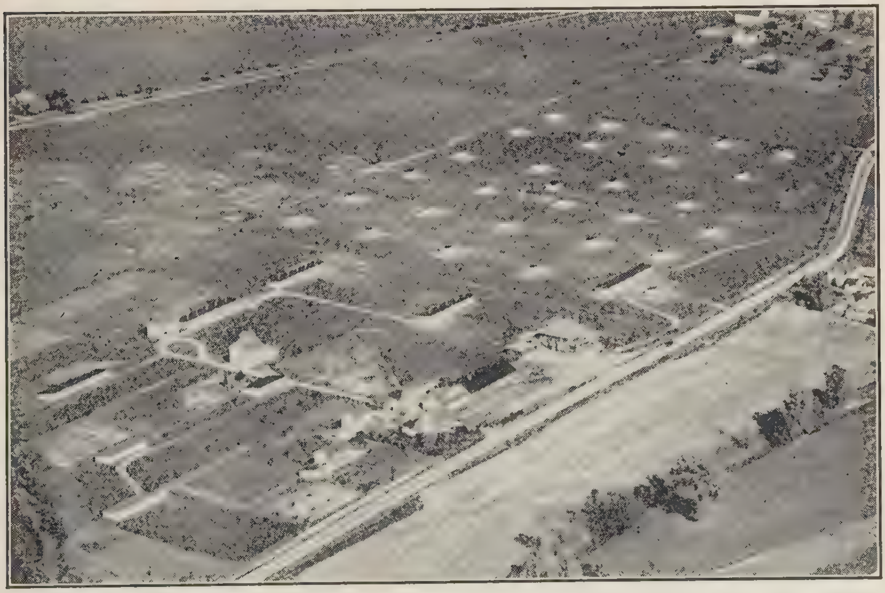

FIG. 229.—An airplane view of the well-laid-out Gasson poultry plant in Ohio, showing the systematic arrangement of laying and brooder houses. (*Photograph by Mr. John P. Gasson.*)

Attractiveness in Poultry Plant Layouts.—Attractiveness is a valuable asset everywhere. It helps to sell things. It is easier to sell eggs, chicks and breeding stock from an attractive poultry plant than from an untidy plant. The houses themselves should be attractive, both inside and outside, and the yards and fences should also be attractive. Bushes and shade trees properly situated add much to the attractiveness of the plant. Neatness and tidiness about the plant enable the owner to take pride in his poultry plant and in his work.

APPENDIX

TABLE 138.—U. S. IMPORTS OF EGGS BY COUNTRIES OF ORIGIN, 1929
(U. S. Dept. of Commerce)

Country	Eggs in shell, dozen	Whole eggs dried, pounds	Whole eggs frozen, pounds	Yolks dried, pounds	Yolks frozen, pounds	Egg albumen dried, pounds	Egg albumen frozen, pounds
Denmark	....	....	....	....	....	2,800	
France	....	....	....	....	....	1,323	
Greece							
Italy							
Germany	1,500	30,400	....	42,200	98,415	40,200	
Netherlands	....	....	....	135,400	13,200	36,057	
United Kingdom	1,122	....	5,270,944	13,559	239,040	8,700	16,600
Switzerland							
Canada	56,642	....	60	2,800	1,330	600	35,490
China	16,985	1,612,026	3,900,693	6,395,080	4,049,507	3,920,869	137,326
Hong Kong	230,607	....	7,540	11,200			
Australia							
New Zealand							
All other countries	1,056	....	900	5,800			
Total, 1929	307,912	1,642,426	9,180,137	6,606,039	4,401,492	4,010,549	189,416
Total, 1928	285,864	1,835,060	11,124,402	4,463,987	3,029,392	2,370,945	649,903

TABLE 139.—U. S. EXPORTS OF EGGS BY COUNTRIES OF DESTINATION
(U. S. Dept. of Commerce)

Country	Eggs in shell, dozen	Whole eggs dried, pounds	Whole eggs frozen, pounds	Yolks dried, pounds	Yolks frozen, pounds	Egg albumen dried, pounds	Egg albumen frozen, pounds
Denmark	41						
France	33	....	....	28,394			
Greece							
Italy				50			
Germany	11	....	....	12			
Netherlands	8						
United Kingdom	138,988	....	....	1,109			
Switzerland							
Canada	771.742	....	....	245,406			
China	1,500						
Hong Kong							
Australia	31						
New Zealand	22,590	....	....	481			
All other countries	11,139,886	....	....	50,254			
Total, 1929	12,074,830	....	....	325,706			
Total, 1928	20,191,627	....	....	508,210			

TABLE 140.—IMPORTS AND EXPORTS EGGS AND POULTRY PRODUCTS, 1929

	Imports	Exports
Shell eggs	307,912 doz.	12,074,830 doz.
Whole eggs, dried	1,642,426 lb.	325,706 lb.
Whole eggs, frozen	9,180,137 lb.	
Yolks, dried	6,606,039 lb.	
Yolks, frozen	4,401,492 lb.	
Egg albumen, dried	4,010,549 lb.	
Egg albumen, frozen prepared or preserved	189,416 lb.	
[1]Live poultry	1,503,467 lb.	448,611 lb.
[1]Dressed poultry	5,196,809 lb.	2,472,574 lb.
[1]Poultry, prepared	553,092 lb.	

[1] Includes poultry other than chickens. Compiled from official records of Bur. Foreign and Domestic Commerce.

Egg Equivalents

1 doz. eggs in shell equal 1 lb. of frozen or liquid egg.
3⅓ lb. liquid whole egg equal 1 lb. dried whole egg.
2¼ lb. liquid yolk equal 1 lb. dried yolk.
7 lb. liquid albumen equal 1 lb. dried albumen.

Quantity of Eggs in a Case and Freight Car

30 doz. eggs equal 1 case (American).
400 to 500 cases equal 1 car (American).
100 to 120 doz. eggs equal 1 case (English and Continental).

Minimum Weight of Freight Car of Poultry and Eggs

Minimum car load (live poultry) equal 18,000 lb.
Minimum car load (dressed poultry) equal 20,000 lb.
Minimum car load (eggs)[1] equal 20,000 lb.

Source of data: Bur. Agr. Econ. Washington, D. C.

Weights and Measures

Centimeters × 0.3937 = inches
Centimeters ÷ 2.54 = inches
Meters × 39.37 = inches
Meters × 3.28 = feet
Millimeters × 0.03937 = inches
Millimeters ÷ 25.4 = inches
Grams ÷ 28.35 = ounces avoirdupois
Watts ÷ 746 = horsepower
Calories × 3.968 = B.t.u. (British thermal unit)
Centigrade × 1.8 + 32 = degrees Fahrenheit
1 ounce = 28.35 grams
1 pound = 453.60 grams
1 cubic foot = 1/27 cubic yard
1 board foot = 144 cubic inches = 1/12 cubic foot
16 ounces = 1 pound
12 inches = 1 foot
3 feet = 1 yard
5½ yards = 1 rod or pole
144 square inches = 1 square foot
9 square feet = 1 square yard
1 bushel barley = 48 pounds
1 bushel oats = 32 pounds
1 bushel corn (shelled) = 56 pounds
1 bushel wheat = 60 pounds

State Agricultural Colleges and Experiment Stations

Alabama: College of Agriculture, Auburn
Arizona: College of Agriculture, Tucson
Arkansas: College of Agriculture, Fayetteville
California: College of Agriculture, Berkeley
Colorado: College of Agriculture, Fort Collins
Connecticut: College of Agriculture, Storrs
Delaware: College of Agriculture, Newark

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[1] Intrastate and certain southwestern states. Transcontinental, 26,000 lb.

Florida: College of Agriculture, Gainesville
Georgia: College of Agriculture, Athens
Idaho: College of Agriculture, Moscow
Illinois: College of Agriculture, Urbana
Indiana: College of Agriculture, Lafayette
Iowa: College of Agriculture, Ames
Kansas: College of Agriculture, Manhattan
Kentucky: College of Agriculture, Lexington
Louisiana: College of Agriculture, Baton Rouge
Maine: College of Agriculture, Orono
Maryland: College of Agriculture, College Park
Massachusetts: College of Agriculture, Amherst
Michigan: College of Agriculture, East Lansing
Minnesota: College of Agriculture, St. Paul
Mississippi: College of Agriculture, A. & M. College
Missouri: College of Agriculture, Columbia
Missouri: Poultry Experiment Station, Mountain Grove
Montana: College of Agriculture, Bozeman
Nebraska: College of Agriculture, Lincoln
Nevada: College of Agriculture, Reno
New Hampshire: College of Agriculture, Durham
New Jersey: College of Agriculture, New Brunswick
New Mexico: College of Agriculture, State College
New York: College of Agriculture, Ithaca
North Carolina: College of Agriculture, Raleigh
North Dakota: College of Agriculture, Fargo
Ohio: College of Agriculture, Columbus
Ohio: Experiment Station, Wooster
Oklahoma: College of Agriculture, Stillwater
Oregon: College of Agriculture, Corvallis
Pennsylvania: College of Agriculture, State College
Rhode Island: College of Agriculture, Kingston
South Carolina: College of Agriculture, Clemson, College
South Dakota: College of Agriculture, Brookings
Tennessee: College of Agriculture, Knoxville
Texas: College of Agriculture, College Station
Utah: College of Agriculture, Logan
Vermont: College of Agriculture, Burlington
Virginia: College of Agriculture, Blacksburg
Washington: College of Agriculture, Pullman
Washington: Western Washington Experiment Station, Puyallup
West Virginia: College of Agriculture, Morgantown
Wisconsin: College of Agriculture, Madison
Wyoming: College of Agriculture, Laramie

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